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J. B. Woodworth.

PRINCIPLES

OF

GEOLOGY.

VOL. III.

Thomas H. Russell

1844

PRINCIPLES

OF

GEOLOGY:

OR, THE

MODERN CHANGES

OF THE EARTH AND ITS INHABITANTS,

CONSIDERED AS ILLUSTRATIVE OF GEOLOGY.

BY

CHARLES LYELL, ESQ., F.R.S.

"The inhabitants of the globe, like all the other parts of it, are subject to change. It is not only the individual that perishes, but whole species."

"A change in the animal kingdom seems to be a part of the order of nature, and is visible in instances to which human power cannot have extended."

PLAYFAIR, *Illustrations of the Huttonian Theory*, § 413.

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PRINCIPLES OF GEOLOGY.

BOOK III.

CHAPTER I.

CHANGES OF THE ORGANIC WORLD NOW IN PROGRESS.

Division of the subject — Examination of the question, Whether species have a real existence in nature? — Importance of this question in geology — Sketch of Lamarck's arguments in favour of the transmutation of species, and his conjectures respecting the origin of existing animals and plants — His theory of the transformation of the orang-outang into the human species.

The last book was occupied with the consideration of the changes brought about on the earth's surface, within the period of human observation, by inorganic agents; such, for example, as rivers, marine currents, volcanos, and earthquakes. But there is another class of phenomena relating to the organic world, which have an equal claim on our attention, if we desire to obtain possession of all the preparatory knowledge respecting the existing course of nature, which may be available in the interpretation of geological monuments. It appeared from our preliminary sketch of the progress of the science, that the most lively interest was excited

among its earlier cultivators, by the discovery of the remains of animals and plants in the interior of mountains frequently remote from the sea. Much controversy arose respecting the nature of these remains, the causes which may have brought them into so singular a position, and the want of a specific agreement between them and known animals and plants. To qualify ourselves to form just views on these curious questions, we must first study the present condition of the animate creation on the globe.

This branch of our inquiry naturally divides itself into two parts: first, we may examine the vicissitudes to which species are subject; secondly, the processes by which certain individuals of these species occasionally become fossil. The first of these divisions will lead us, among other topics, to inquire first, whether species have a real and permanent existence in nature? or whether they are capable, as some naturalists pretend, of being indefinitely modified in the course of a long series of generations? Secondly, whether, if species have a real existence, the individuals composing them have been derived originally from many similar stocks, or each from one only, the descendants of which have spread themselves gradually from a particular point over the habitable lands and waters? Thirdly, how far the duration of each species of animal and plant is limited by its dependence on certain fluctuating and temporary conditions in the state of the animate and inanimate world? Fourthly, whether there be proofs of the successive extermination of species in the ordinary course of nature, and whether there be any reason for conjecturing that new animals and plants are created from time to time, to supply their place?

Whether species have a real existence in nature.— Before we can advance a step in our proposed inquiry, we must be able to define precisely the meaning which we attach to the term species. This is even more necessary in geology than in the ordinary studies of the naturalist; for they who deny that such a thing as a species exists, concede nevertheless that a botanist or zoologist may reason as if the specific character were constant, because they confine their observations to a brief period of time. Just as the geographer, in constructing his maps from century to century, may proceed as if the apparent places of the fixed stars remained absolutely the same, and as if no alteration were brought about by the precession of the equinoxes; so, it is said, in the organic world, the stability of a species may be taken as absolute, if we do not extend our views beyond the narrow period of human history; but let a sufficient number of centuries elapse, to allow of important revolutions in climate, physical geography, and other circumstances, and the characters, say they, of the descendants of common parents may deviate indefinitely from their original type.

Now, if these doctrines be tenable, we are at once presented with a principle of incessant change in the organic world; and no degree of dissimilarity in the plants and animals which may formerly have existed, and are found fossil, would entitle us to conclude that they may not have been the prototypes and progenitors of the species now living. Accordingly M. Geoffroy St. Hilaire has declared his opinion, that there has been an uninterrupted succession in the animal kingdom, effected by means of generation, from the earliest ages of the world up to the present day, and that the ancient animals whose remains have been

preserved in the strata, however different, may nevertheless have been the ancestors of those now in being. This notion is not very generally received, but we are not warranted in assuming the contrary, without fully explaining the data and reasoning by which it may be refuted.

I shall begin by stating as concisely as possible all the facts and ingenious arguments by which the theory has been supported; and for this purpose I cannot do better than offer the reader a rapid sketch of Lamarck's statement of the proofs which he regards as confirmatory of the doctrine, and which he has derived partly from the works of his predecessors and in part from original investigations.

His proofs and inferences will be best considered in the order in which they appear to have influenced his mind, and I shall then point out some of the results to which he was led while boldly following out his principles to their legitimate consequences.

Lamarck's arguments in favour of the transmutation of species.—The name of species, observes Lamarck, has been usually applied to "every collection of similar individuals produced by other individuals like themselves." * This definition, he admits, is correct; because every living individual bears a very close resemblance to those from which it springs. But this is not all which is usually implied by the term species; for the majority of naturalists agree with Linnæus in supposing that all the individuals propagated from one stock have certain distinguishing characters in common, which will never vary, and which have remained the same since the creation of each species.

* Phil. Zool. tom. i. p. 54.

In order to shake this opinion, Lamarck enters upon the following line of argument: — The more we advance in the knowledge of the different organized bodies which cover the surface of the globe, the more our embarrassment increases, to determine what ought to be regarded as a species, and still more how to limit and distinguish genera. In proportion as our collections are enriched, we see almost every void filled up, and all our lines of separation effaced; we are reduced to arbitrary determinations, and are sometimes fain to seize upon the slight differences of mere varieties, in order to form characters for what we choose to call a species; and sometimes we are induced to pronounce individuals but slightly differing, and which others regard as true species, to be varieties.

The greater the abundance of natural objects assembled together, the more do we discover proofs that every thing passes by insensible shades into something else: that even the more remarkable differences are evanescent, and that nature has for the most part, left us nothing at our disposal for establishing distinctions, save trifling, and, in some respects, puerile particularities.

We find that many genera amongst animals and plants are of such an extent, in consequence of the number of species referred to them, that the study and determination of these last has become almost impracticable. When the species are arranged in a series, and placed near to each other, with due regard to their natural affinities, they each differ in so minute a degree from those next adjoining, that they almost melt into each other, and are in a manner confounded together. If we see isolated species, we may pre-

sume the absence of some more closely connected, and which have not yet been discovered. Already are there genera, and even entire orders — nay, whole classes, which present an approximation to the state of things here indicated.

If, when species have been thus placed in a regular series, we select one, and then, making a leap over several intermediate ones, we take a second, at some distance from the first, these two will, on comparison, be seen to be very dissimilar: and it is in this manner that every naturalist begins to study the objects which are at his own door. He then finds it an easy task to establish generic and specific distinctions; and it is only when his experience is enlarged, and when he has made himself master of the intermediate links that his difficulties and ambiguities begin. But while we are thus compelled to resort to trifling and minute characters in our attempt to separate species, we find a striking disparity between individuals which we know to have descended from a common stock; and these newly acquired peculiarities are regularly transmitted from one generation to another, constituting what are called *races*.

From a great number of facts, continues the author, we learn that in proportion as the individuals of one of our species change their situation, climate, and manner of living, they change also, by little and little, the consistence and proportions of their parts, their form, their faculties, and even their organization, in such a manner that every thing in them comes at last to participate in the mutations to which they have been exposed. Even in the same climate, a great difference of situation and exposure causes individuals to vary; but if these individuals continue to live and to be repro-

duced under the same difference of circumstances, distinctions are brought about in them which become in some degree essential to their existence. In a word, at the end of many successive generations, these individuals, which originally belonged to another species, are transformed into a new and distinct species.*

Thus, for example, if the seeds of a grass, or any other plant which grows naturally in a moist meadow, be accidentally transported, first to the slope of some neighbouring hill, where the soil, although at a greater elevation, is damp enough to allow the plant to live; and if, after having lived there, and having been several times regenerated, it reaches by degrees the drier and almost arid soil of a mountain declivity, it will then, if it succeeds in growing, and perpetuates itself for a series of generations, be so changed that botanists who meet with it will regard it as a particular species.† The unfavourable climate in this case, deficiency of nourishment, exposure to the winds, and other causes, give rise to a stunted and dwarfish race, with some organ more developed than others, and having proportions often quite peculiar.

What nature brings about in a great lapse of time, we occasion suddenly by changing the circumstances in which a species has been accustomed to live. All are aware that vegetables taken from their birth-place, and cultivated in gardens, undergo changes which render them no longer recognizable as the same plants. Many which were naturally hairy become smooth, or nearly so; a great number of such as were creepers and trailed along the ground, rear their stalks and grow erect. Others lose their thorns or asperities;

* Phil. Zool. tom. i. p. 62. † Ibid.

others, again, from the ligneous state which their stem possessed in hot climates, where they were indigenous, pass to the herbaceous; and, among them, some which were perennials become mere annuals. So well do botanists know the effects of such changes of circumstances, that they are averse to describe species from garden specimens, unless they are sure that they have been cultivated for a very short period.

"Is not the cultivated wheat" (*Triticum sativum*), asks Lamarck, "a vegetable brought by man into the state in which we now see it? Let any one tell me in what country a similar plant grows wild, unless where it has escaped from cultivated fields? Where do we find in nature our cabbages, lettuces, and other culinary vegetables, in the state in which they appear in our gardens? Is it not the same in regard to a great quantity of animals which domesticity has changed or considerably modified?" * Our domestic fowls and pigeons are unlike any wild birds. Our domestic ducks and geese have lost the faculty of raising themselves into the higher regions of the air, and crossing extensive countries in their flight, like the wild ducks and wild geese from which they were originally derived. A bird which we breed in a cage cannot, when restored to liberty, fly like others of the same species which have been always free. This small alteration of circumstances, however, has only diminished the power of flight, without modifying the form of any part of the wings. But when individuals of the same race are retained in captivity during a considerable length of time, the form even of their parts is gradually made to differ, especially if climate, nourishment, and other circumstances be also altered.

* Phil. Zool. tom. i. p. 227.

The numerous races of dogs which we have produced by domesticity are nowhere to be found in a wild state. In nature we should seek in vain for mastiffs, harriers, spaniels, greyhounds, and other races, between which the differences are sometimes so great that they would be readily admitted as specific between wild animals; "yet all these have sprung originally from a single race, at first approaching very near to a wolf, if, indeed, the wolf be not the true type which at some period or other was domesticated by man."

Although important changes in the nature of the places which they inhabit modify the organization of animals as well as vegetables; yet the former, says Lamarck, require more time to complete a considerable degree of transmutation; and, consequently, we are less sensible of such occurrences. Next to a diversity of the medium in which animals or plants may live, the circumstances which have most influence in modifying their organs are differences in exposure, climate, the nature of the soil, and other local particulars. These circumstances are as varied as are the characters of the species, and, like them, pass by insensible shades into each other, there being every intermediate gradation between the opposite extremes. But each locality remains for a very long time the same, and is altered so slowly that we can only become conscious of the reality of the change by consulting geological monuments, by which we learn that the order of things which now reigns in each place has not always prevailed, and by inference anticipate that it will not always continue the same.*

Every considerable alteration in the local circum-

* Phil. Zool. tom. i. p. 232.

stances in which each race of animals exists causes a change in their wants, and these new wants excite them to new actions and habits. These actions require the more frequent employment of some parts before but slightly exercised, and then greater development follows as a consequence of their more frequent use. Other organs no longer in use are impoverished and diminished in size, nay, are sometimes entirely annihilated, while in their place new parts are insensibly produced for the discharge of new functions.*

I must here interrupt the author's argument, by observing, that no positive fact is cited to exemplify the substitution of some *entirely new* sense, faculty, or organ, in the room of some other suppressed as useless. All the instances adduced go only to prove that the dimensions and strength of members and the perfection of certain attributes may, in a long succession of generations, be lessened and enfeebled by disuse; or, on the contrary, be matured and augmented by active exertion; just as we know that the power of scent is feeble in the greyhound, while its swiftness of pace and its acuteness of sight are remarkable — that the harrier and stag-hound, on the contrary, are comparatively slow in their movements, but excel in the sense of smelling.

It was necessary to point out to the reader this important chasm in the chain of evidence, because he might otherwise imagine that I had merely omitted the illustrations for the sake of brevity, but the plain truth is, that there were no examples to be found; and when Lamarck talks "of the efforts of internal senti-

* Phil. Zool. tom. i. p. 234.

ment," "the influence of subtle fluids," and "acts of organization," as causes whereby animals and plants may acquire *new organs*, he substitutes names for things; and, with a disregard to the strict rules of induction, resorts to fictions, as ideal as the "plastic virtue," and other phantoms, of the geologists of the middle ages.

It is evident that, if some well-authenticated facts could have been adduced to establish one complete step in the process of transformation, such as the appearance, in individuals descending from a common stock, of a sense or organ entirely new, and a complete disappearance of some other enjoyed by their progenitors, time alone might then be supposed sufficient to bring about any amount of metamorphosis. The gratuitous assumption, therefore, of a point so vital to the theory of transmutation, was unpardonable on the part of its advocate.

But to proceed with the system: it being assumed as an undoubted fact, that a change of external circumstances may cause one organ to become entirely obsolete, and a new one to be developed, such as never before belonged to the species, the following proposition is announced, which, however staggering and absurd it may seem, is logically deduced from the assumed premises. It is not the organs, or, in other words, the nature and form of the parts of the body of an animal, which have given rise to its habits, and its particular faculties; but, on the contrary, its habits, its manner of living, and those of its progenitors, have in the course of time determined the form of its body, the number and condition of its organs, in short, the faculties which it enjoys. Thus otters, beavers, waterfowl, turtles, and frogs, were not made web-footed in

order that they might swim; but their wants having attracted them to the water in search of prey, they stretched out the toes of their feet to strike the water and move rapidly along its surface. By the repeated stretching of their toes, the skin which united them at the base acquired a habit of extension, until, in the course of time, the broad membranes which now connect their extremities were formed.

In like manner, the antelope and the gazelle were not endowed with light agile forms, in order that they might escape by flight from carnivorous animals; but, having been exposed to the danger of being devoured by lions, tigers, and other beasts of prey, they were compelled to exert themselves in running with great celerity; a habit which, in the course of many generations, gave rise to the peculiar slenderness of their legs, and the agility and elegance of their forms.

The camelopard was not gifted with a long flexible neck because it was destined to live in the interior of Africa, where the soil was arid and devoid of herbage; but, being reduced by the nature of that country to support itself on the foliage of lofty trees, it contracted a habit of stretching itself up to reach the high boughs, until its neck became so elongated that it could raise its head to the height of twenty feet above the ground.

Another line of argument is then entered upon, in further corroboration of the instability of species. In order, it is said, that individuals should perpetuate themselves unaltered by generation, those belonging to one species ought never to ally themselves to those of another; but such sexual unions do take place, both among plants and animals; and although the offspring of such irregular connexions are usually sterile, yet such is not always the case. Hybrids have some-

times proved prolific, where the disparity between the species was not too great; and by this means alone, says Lamarck, varieties may gradually be created by near alliances, which would become races, and in the course of time would constitute what we term species.*

But if the soundness of all these arguments and inferences be admitted, we are next to inquire, what were the original types of form, organization, and instinct, from which the diversities of character, as now exhibited by animals and plants, have been derived? We know that individuals which are mere varieties of the same species would, if their pedigree could be traced back far enough, terminate in a single stock; so, according to the train of reasoning before described, the species of a genus, and even the genera of a great family, must have had a common point of departure. What, then, was the single stem from which so many varieties of form have ramified? Were there many of these, or are we to refer the origin of the whole animate creation, as the Egyptian priests did that of the universe, to a single egg?

In the absence of any positive data for framing a theory on so obscure a subject, the following considerations were deemed of importance to guide conjecture.

In the first place, if we examine the whole series of known animals, from one extremity to the other, when they are arranged in the order of their natural relations, we find that we may pass progressively, or, at least, with very few interruptions, from beings of more simple to those of a more compound structure; and, in proportion as the complexity of their organization increases, the number and dignity of their faculties

* Phil. Zool. p. 64.

increase also. Among plants, a similar approximation to a graduated scale of being is apparent. Secondly, it appears, from geological observations, that plants and animals of more simple organization existed on the globe before the appearance of those of more compound structure, and the latter were successively formed at more modern periods: each new race being more fully developed than the most perfect of the preceding era.

Of the truth of the last-mentioned geological theory, Lamarck seems to have been fully persuaded; and he also shows that he was deeply impressed with a belief prevalent amongst the older naturalists, that the primeval ocean invested the whole planet long after it became the habitation of living beings; and thus he was inclined to assert the priority of the types of marine animals to those of the terrestrial, so as to fancy, for example, that the testacea of the ocean existed first, until some of them, by gradual evolution, were *improved* into those inhabiting the land.

These speculative views had already been, in a great degree, anticipated by Demaillet in his Telliamed, and by several modern writers; so that the tables were completely turned on the philosophers of antiquity, with whom it was a received maxim, that created things were always most perfect when they came first from the hands of their Maker; and that there was a tendency to progressive deterioration in sublunary things when left to themselves —

——— omnia fatis
In pejus ruere, ac retrò sublapsa referri.

So deeply was the faith of the ancient schools of philosophy imbued with this doctrine, that, to check

this universal proneness to degeneracy, nothing less than the re-intervention of the Deity was thought adequate; and it was held, that thereby the order, excellence, and pristine energy of the moral and physical world had been repeatedly restored.

But when the possibility of the indefinite modification of individuals descending from common parents was once assumed, as also the geological inference respecting the progressive development of organic life, it was natural that the ancient dogma should be rejected, or rather reversed, and that the most simple and imperfect forms and faculties should be conceived to have been the originals whence all others were developed. Accordingly, in conformity to these views, inert matter was supposed to have been first endowed with life; until, in the course of ages, sensation was superadded to mere vitality: sight, hearing, and the other senses were afterwards acquired; then instinct and the mental faculties; until, finally, by virtue of the tendency of things to *progressive improvement*, the irrational was developed into the rational.

The reader, however, will immediately perceive that when all the higher order of plants and animals were thus supposed to be comparatively modern, and to have been derived in a long series of generations from those of more simple conformation, some further hypothesis became indispensable, in order to explain why, after an indefinite lapse of ages, there were still so many beings of the simplest structure. Why have the majority of existing creatures remained stationary throughout this long succession of epochs, while others have made such prodigious advances? Why are there such multitudes of infusoria and polyps, or of confervæ and other cryptogamic plants? Why, moreover, has

the process of development acted with such unequal and irregular force on those classes of beings which have been greatly perfected, so that there are wide chasms in the series; gaps so enormous, that Lamarck fairly admits we can never expect to fill them up by future discoveries?

The following hypothesis was provided to meet these objections. Nature, we are told, is not an intelligence, nor the Deity; but a delegated power — a mere instrument — a piece of mechanism acting by necessity — an order of things constituted by the Supreme Being, and subject to laws which are the expressions of his will. This Nature is *obliged* to proceed gradually in all her operations; she cannot produce animals and plants of all classes at once, but must always begin by the formation of the most simple kinds, and out of them elaborate the more compound, adding to them, successively, different systems of organs, and multiplying more and more their number and energy.

This nature is daily engaged in the formation of the elementary rudiments of animal and vegetable existence, which correspond to what the ancients termed *spontaneous generation*. She is always beginning anew, day by day, the work of creation, by forming monads, or "rough draughts" (ébauches), which are the only living things she gives birth to *directly*.

There are distinct primary rudiments of plants and animals, and *probably* of each of the great divisions of the animal and vegetable kingdoms.* These are gradually developed into the higher and more perfect classes by the slow but unceasing agency of two influential principles: first, *the tendency to progressive*

* Animaux sans Vert. tom. i. p. 56. Introduction.

advancement in organization, accompanied by greater dignity in instinct, intelligence, &c.; secondly, *the force of external circumstances*, or of variations in the physical condition of the earth, or the mutual relations of plants and animals. For, as species spread themselves gradually over the globe, they are exposed from time to time to variations in climate, and to changes in the quantity and quality of their food; they meet with new plants and animals which assist or retard their development, by supplying them with nutriment, or destroying their foes. The nature, also, of each locality, is in itself fluctuating; so that, even if the relation of other animals and plants were invariable, the habits and organization of species would be modified by the influence of local revolutions.

Now, if the first of these principles, *the tendency to progressive development*, were left to exert itself with perfect freedom, it would give rise, says Lamarck, in the course of ages, to a graduated scale of being, where the most insensible transition might be traced from the simplest to the most compound structure, from the humblest to the most exalted degree of intelligence. But, in consequence of the perpetual interference of the *external causes* before mentioned, this regular order is greatly interfered with, and an approximation only to such a state of things is exhibited by the animate creation, the progress of some races being retarded by unfavourable, and that of others accelerated by favourable, combinations of circumstances. Hence, all kinds of anomalies interrupt the continuity of the plan; and chasms, into which whole genera or families might be inserted, are seen to separate the nearest existing portions of the series.

Lamarck's theory of the transformation of the orang-outang into the human species.—Such is the machinery of the Lamarckian system; but the reader will hardly, perhaps, be able to form a perfect conception of so complicated a piece of mechanism, unless it is exhibited in motion, so that we may see in what manner it can work out, under the author's guidance, all the extraordinary effects which we behold in the present state of the animate creation. I have only space for exhibiting a small part of the entire process by which a complete metamorphosis is achieved, and shall therefore, omit the mode by which, after a countless succession of generations, a small gelatinous body is transformed into an oak or an ape; passing on at once to the last grand step in the progressive scheme, by which the orang-outang, having been already evolved out of a monad, is made slowly to attain the attributes and dignity of man.

One of the races of quadrumanous animals which had reached the highest state of perfection, lost, by constraint of circumstances (concerning the exact nature of which tradition is unfortunately silent), the habit of climbing trees, and of hanging on by grasping the boughs with their feet as with hands. The individuals of this race being obliged, for a long series of generations, to use their feet exclusively for walking, and ceasing to employ their hands as feet, were transformed into bimanous animals, and what before were thumbs became mere toes, no separation being required when their feet were used solely for walking. Having acquired a habit of holding themselves upright, their legs and feet assumed, insensibly, a conformation fitted to support them in an erect attitude, till at last these

animals could no longer go on all-fours without much inconvenience.

The Angola orang (*Simia troglodytes*, Linn.) is the most perfect of animals; much more so than the Indian orang (*Simia Satyrus*), which has been called the orang-outang, although *both* are *very inferior* to man in corporeal powers and intelligence. These animals frequently hold themselves upright; but their organization has *not yet* been sufficiently modified to sustain them habitually in this attitude, so that the standing posture is very uneasy to them. When the Indian orang is compelled to take flight from pressing danger, he immediately falls down upon all-fours, showing clearly that this was the original position of the animal. Even in man, whose organization, in the course of a long series of generations, has advanced so much farther, the upright posture is fatiguing, and can be supported only for a limited time, and by aid of the contraction of many muscles. If the vertebral column formed the axis of the human body, and supported the head and all the other parts in equilibrium, then might the upright position be a state of repose: but, as the human head does not articulate in the centre of gravity, as the chest, belly, and other parts press almost entirely forward with their whole weight, and as the vertebral column reposes upon an oblique base, a watchful activity is required to prevent the body from falling. Children which have large heads and prominent bellies can hardly walk at the end even of two years; and their frequent tumbles indicate the natural tendency in man to resume the quadrupedal state.

Now, when so much progress had been made by the quadrumanous animals before mentioned, that they

could hold themselves habitually in an erect attitude, and were accustomed to a wide range of vision, and ceased to use their jaws for fighting and tearing, or for clipping herbs for food, their snout became gradually shorter, their incisor teeth became vertical, and the facial angle grew more open.

Among other ideas which the natural *tendency to perfection* engendered, the desire of ruling suggested itself, and this race succeeded at length in getting the better of the other animals, and made themselves masters of all those spots on the surface of the globe which best suited them. They drove out the animals which approached nearest them in organization and intelligence, and which were in a condition to dispute with them the good things of this world, forcing them to take refuge in deserts, woods, and wildernesses, where their multiplication was checked, and the progressive development of their faculties retarded; while, in the mean time, the dominant race spread itself in every direction, and lived in large companies, where new wants were successively created, exciting them to industry, and gradually perfecting their means and faculties.

In the supremacy and increased intelligence acquired by the ruling race, we see an illustration of the natural tendency of the organic world to grow more perfect; and, in their influence in repressing the advance of others, an example of one of those disturbing causes before enumerated, that *force of external circumstances* which causes such wide chasms in the regular series of animated being.

When the individuals of the dominant race became very numerous, their ideas greatly increased in number, and they felt the necessity of communicating them

to each other, and of augmenting and varying the signs proper for the communication of ideas. Meanwhile the inferior quadrumanous animals, although most of them were gregarious, acquired no new ideas, being persecuted and restless in the deserts, and obliged to fly and conceal themselves, so that they conceived no new wants. Such ideas as they already had remained unaltered, and they could dispense with the communication of the greater part of these. To make themselves, therefore, understood by their fellows, required merely a few movements of the body or limbs — whistling, and the uttering of certain cries varied by the inflexions of the voice.

On the contrary, the individuals of the ascendant race, animated with a desire of interchanging their ideas, which became more and more numerous, were prompted to multiply the means of communication, and were no longer satisfied with mere pantomimic signs, nor even with all the possible inflexions of the voice; but made continual efforts to acquire the power of uttering articulate sounds, employing a few at first, but afterwards varying and perfecting them according to the increase of their wants. The habitual exercise of their throat, tongue, and lips, insensibly modified the conformation of these organs, until they became fitted for the faculty of speech.*

In effecting this mighty change, "the exigencies of the individuals were the sole agents; they gave rise to efforts, and the organs proper for articulating sounds were developed by their habitual employment." Hence, in this peculiar race, the origin of the admirable faculty of speech; hence also the diversity of languages, since

* Lamarck's Phil. Zool. tom. i. p. 356.

the distance of places where the individuals composing the race established themselves soon favoured the corruption of conventional signs.*

In conclusion, it may be proper to observe that the above sketch of the Lamarckian theory is no exaggerated picture, and those passages which have probably excited the greatest surprise in the mind of the reader are literal translations from the original.

* Lamarck's Phil. Zool. tom. i. p. 357.

CHAPTER II.

TRANSMUTATION OF SPECIES — *continued.*

Recapitulation of the arguments in favour of the theory of transmutation of species — Their insufficiency — Causes of difficulty in discriminating species — Some varieties possibly more distinct than certain individuals of distinct species — Variability in a species consistent with a belief that the limits of deviation are fixed — No facts of transmutation authenticated — Varieties of the Dog — the Dog and Wolf distinct species — Mummies of various animals from Egypt identical in character with living individuals — Seeds and plants from the Egyptian tombs — Modifications produced in plants by agriculture and gardening.

The theory of the transmutation of species, considered in the last chapter, has met with some degree of favour from many naturalists, from their desire to dispense, as far as possible, with the repeated intervention of a First Cause, as often as geological monuments attest the successive appearance of new races of animals and plants, and the extinction of those pre-existing. But, independently of a predisposition to account, if possible, for a series of changes in the organic world by the regular action of secondary causes, we have seen that in truth many perplexing difficulties present themselves to one who attempts to establish the nature and reality of the specific character. And if once there appears ground of reasonable doubt, in regard to the

constancy of species, the amount of transformation which they are capable of undergoing may seem to resolve itself into a mere question of the quantity of time assigned to the past duration of animate existence.

Before entering upon the reasons which may be adduced for rejecting Lamarck's hypothesis, I shall recapitulate, in a few words, the phenomena, and the whole train of thought, by which I conceive it to have been suggested, and which have gained for this and analogous theories, both in ancient and modern times, a considerable number of votaries.

In the first place, the various groups into which plants and animals may be thrown seem almost invariably, to a beginner, to be so natural, that he is usually convinced at first, as was Linnæus to the last, "that genera are as much founded in nature as the species which compose them." * When, by examining the numerous intermediate gradations the student finds all lines of demarcation to be in most instances obliterated, even where they at first appeared most distinct, he grows more and more sceptical as to the real existence of genera, and finally regards them as mere arbitrary and artificial signs, invented, like those which serve to distinguish the heavenly constellations, for the convenience of classification, and having as little pretensions to reality.

Doubts are then engendered in his mind as to whether species may not also be equally unreal. The student is probably first struck with the phenomenon, that some individuals are made to deviate widely from the ordinary type by the force of peculiar circum-

* Genus omne est naturale, in primordio tale creatum, &c. Phil. Bot. § 159. See also ibid. § 162.

stances, and with the still more extraordinary fact, that the newly acquired peculiarities are faithfully transmitted to the offspring. How far, he asks, may such variations extend in the course of indefinite periods of time, and during great vicissitudes in the physical condition of the globe? His growing incertitude is at first checked by the reflection, that nature has forbidden the intermixture of the descendants of distinct original stocks, or has, at least, entailed sterility on their offspring, thereby preventing their being confounded together; and pointing out that a multitude of distinct types must have been created in the beginning, and must have remained pure and uncorrupted to this day.

Relying on this general law, he endeavours to solve each difficult problem by direct experiment, until he is again astounded by the phenomenon of a prolific hybrid, and still more by an example of a hybrid perpetuating itself throughout several generations in the vegetable world. He then feels himself reduced to the dilemma of choosing between two alternatives; either to reject the test, or to declare that the two species, from the union of which the fruitful progeny has sprung, were mere varieties. If he prefer the latter, he is compelled to question the reality of the distinctness of all other supposed species which differ no more than the parents of such prolific hybrids: for although he may not be enabled immediately to procure, in all such instances, a fruitful offspring; yet experiments show, that after repeated failures, the union of two recognized species may at last, under very favourable circumstances, give birth to a fertile progeny. Such circumstances, therefore, the naturalist

may conceive to have occurred again and again, in the course of a great lapse of ages.

His first opinions are now fairly unsettled, and every stay at which he has caught has given way one after another; he is in danger of falling into any new and visionary doctrine which may be presented to him; for he now regards every part of the animate creation as void of stability, and in a state of continual flux. In this mood he encounters the Geologist, who relates to him how there have been endless vicissitudes in the shape and structure of organic beings in former ages — how the approach to the present system of things has been gradual — that there has been a progressive development of organization subservient to the purposes of life, from the most simple to the most complex state — that the appearance of man is the last phenomenon in a long succession of events; and finally, that a series of physical revolutions can be traced in the inorganic world, coeval and coextensive with those of organic nature.

These views seem immediately to confirm all his preconceived doubts as to the stability of the specific character, and he begins to think there may exist an inseparable connection between a series of changes in the inanimate world, and the capability of the species to be indefinitely modified by the influence of external circumstances. Henceforth his speculations know no definite bounds; he gives the rein to conjecture, and fancies that the outward form, internal structure, instinctive faculties, nay, that reason itself may have been gradually developed from some of the simplest states of existence — that all animals, that man himself, and the irrational beings, may have had one common origin; that all may be parts of one continuous and

progressive scheme of development, from the most imperfect to the more complex; in fine, he renounces his belief in the high genealogy of his species, and looks forward, as if in compensation, to the future perfectibility of man in his physical, intellectual, and moral attributes.

Let us now proceed to consider what is defective in evidence, and what fallacious in reasoning, in the grounds of these strange conclusions. Blumenbach judiciously observes, that "no general rule can be laid down for determining the distinctness of species, as there is no particular class of characters which can serve as a criterion. In each case we must be guided by *analogy* and *probability*." The multitude, in fact, and complexity of the proofs to be weighed, is so great, that we can only hope to obtain presumptive evidence, and we must, therefore, be the more careful to derive our general views as much as possible from those observations where the chances of deception are least. We must be on our guard not to tread in the footsteps of the naturalists of the middle ages, who believed the doctrine of spontaneous generation to be applicable to all those parts of the animal and vegetable kingdoms which they least understood, in direct contradiction to the analogy of all the parts best known to them; and who, when at length they found that insects and cryptogamous plants were also propagated from eggs or seeds, still persisted in retaining their old prejudices respecting the infusory animalcules and other minute beings, the generation of which had not then been demonstrated by the microscope to be governed by the same laws.

Lamarck has, indeed, attempted to raise an argument in favour of his system, out of the very confusion

which has arisen in the study of some orders of animals and plants, in consequence of the slight shades of difference which separate the new species discovered within the last half century. That the embarrassment of those who attempt to classify and distinguish the new acquisitions, poured in such multitudes into our museums, should increase with the augmentation of their number, is quite natural; since to obviate this it is not enough that our powers of discrimination should keep pace with the increase of the objects, but we ought to possess greater opportunities of studying each animal and plant in all stages of its growth, and to know profoundly their history, their habits, and physiological characters, throughout several generations; for, in proportion as the series of known animals grows more complete, none can doubt that there is a nearer approximation to a graduated scale of being; and thus the most closely allied species will be found to possess a greater number of characters in common.

Causes of the difficulty of discriminating species.— But, in point of fact, our new acquisitions consist, more and more as we advance, of specimens brought from foreign and often very distant and barbarous countries. A large proportion have never even been seen alive by scientific inquirers. Instead of having specimens of the young, the adult, and the aged individuals of each sex, and possessing means of investigating the anatomical structure, the peculiar habits, and instincts of each, what is usually the state of our information? A single specimen, perhaps, of a dried plant, or a stuffed bird or quadruped; a shell, without the soft parts of the animal; an insect in one stage of its numerous transformations; — these are the scanty and imperfect data which the naturalist possesses.

Such information may enable us to separate species which stand at a considerable distance from each other; but we have no right to expect any thing but difficulty and ambiguity, if we attempt, from such imperfect opportunities, to obtain distinctive marks for defining the characters of species which are closely related.

If Lamarck could introduce so much certainty and precision into the classification of several thousand species of recent and fossil shells, notwithstanding the extreme remoteness of the organization of these animals from the type of those vertebrated species which are best known, and in the absence of so many of the living inhabitants of shells, we are led to form an exalted conception of the degree of exactness to which specific distinctions are capable of being carried, rather than to call in question their reality.

When our data are so defective, the most acute naturalist must expect to be sometimes at fault, and, like the novice, to overlook essential points of difference, passing unconsciously from one species to another, until, like one who is borne along in a current, he is astonished, on looking back, at observing that he has reached a point so remote from that whence he set out.

It is by no means improbable, that, when the series of species of certain genera is very full, they may be found to differ less widely from each other than do the mere varieties or races of certain species. If such a fact could be established, it would, undoubtedly, diminish the chance of our obtaining certainty in our results; but it would by no means overthrow our confidence in the reality of species.

Some mere varieties possibly more distinct than certain individuals of distinct species.—It is almost necessary,

indeed, to suppose that varieties will differ in some cases more decidedly than some species, if we admit that there is a graduated scale of being, and assume that the following laws prevail in the economy of the animate creation:—first, that the organization of individuals is capable of being modified to a limited extent by the force of external causes; secondly, that these modifications are, to a certain extent, transmissible to their offspring; thirdly, that there are fixed limits, beyond which the descendants from common parents can never deviate from a certain type; fourthly, that each species springs from one original stock, and can never be permanently confounded by intermixing with the progeny of any other stock; fifthly, that each species shall endure for a considerable period of time. Now, let us assume, for the present, these rules hypothetically, and see what consequences may naturally be expected to result from them.

We must suppose that when the Author of Nature creates an animal or plant, all the possible circumstances in which its descendants are destined to live are foreseen, and that an organization is conferred upon it which will enable the species to perpetuate itself and survive under all the varying circumstances to which it must be inevitably exposed. Now, the range of variation of circumstances will differ essentially in almost every case. Let us take, for example, any one of the most influential conditions of existence, such as temperature. In some extensive districts near the equator, the thermometer might never vary, throughout several thousand centuries, for more than 20° Fahrenheit; so that if a plant or animal be provided with an organization fitting it to endure such a range, it may continue on the globe for that immense

period, although every individual might be liable at once to be cut off by the least possible excess of heat or cold beyond the determinate degree. But if a species be placed in one of the temperate zones, and have a constitution conferred on it capable of supporting a similar range of temperature only, it will inevitably perish before a single year has passed away.

Humboldt has shown that, at Cumana, within the tropics, there is a difference of only four degrees (Fahr.) between the temperature of the warmest and coldest months; whereas, in the temperate zones, the annual variation amounts to about 60°, and the extreme range of the thermometer in Canada is not less than 90°.

The same remark might be applied to any other condition, as food, for example: it may be foreseen that the supply will be regular throughout indefinite periods in one part of the world, and in another very precarious and fluctuating both in kind and quantity. Different qualifications may be required for enabling species to live for a considerable time under circumstances so changeable. If, then, temperature and food be among those external causes which, according to certain laws of animal and vegetable physiology, modify the organization, form, or faculties, of individuals, we instantly perceive that the degrees of variability from a common standard must differ widely in the two cases above supposed; since there is a necessity of accommodating a species in one case to a much greater latitude of circumstances than in the other.

If it be a law, for instance, that scanty sustenance should check those individuals in their growth which are enabled to accommodate themselves to privations of this kind, and that a parent, prevented in this

manner from attaining the size proper to its species, should produce a dwarfish offspring, a stunted race will arise, as is remarkably exemplified in some varieties of the horse and dog. The difference of stature in some races of dogs, when compared to others, is as one to five in linear dimensions, making a difference of a hundred-fold in volume.* Now, there is good reason to believe that species in general are by no means susceptible of existing under a diversity of circumstances, which may give rise to such a disparity in size, and, consequently, there will be a multitude of distinct species, of which no two adult individuals can ever depart so widely from a certain standard of dimensions as the mere varieties of certain other species — the dog, for instance. Now, we have only to suppose that what is true of size, may also hold in regard to colour and many other attributes; and it will at once follow, that the degree of possible discordance between varieties of the same species may, in certain cases, exceed the utmost disparity which can arise between two individuals of many distinct species.

The same remarks may hold true in regard to instincts; for, if it be foreseen that one species will have to encounter a great variety of foes, it may be necessary to arm it with great cunning and circumspection, or with courage or other qualities capable of developing themselves on certain occasions; such, for example as those migratory instincts which are so remarkably exhibited at particular periods, after they have remained dormant for many generations. The history and habits of one variety of such a species may often differ more considerably from some other than

* Cuvier, Disc. Prélim. p. 128. sixth edition.

those of many distinct species which have no such latitude of accommodation to circumstances.

Extent of known variability in species. — Lamarck has somewhat misstated the idea commonly entertained of a species; for it is not true that naturalists in general assume that the organization of an animal or plant remains absolutely constant, and that it can never vary in any of its parts.* All must be aware that circumstances influence the habits, and that the habits may alter the state of the parts and organs; but the difference of opinion relates to the extent to which these modifications of the habits and organs of a particular species may be carried.

Now, let us first inquire what positive facts can be adduced in the history of known species, to establish a great and permanent amount of change in the form, structure, or instinct of individuals descending from some common stock. The best authenticated examples of the extent to which species can be made to vary may be looked for in the history of domesticated animals and cultivated plants. It usually happens, that those species, both of the animal and vegetable kingdom, which have the greatest pliability of organization, those which are most capable of accommodating themselves to a great variety of new circumstances, are most serviceable to man. These only can be carried by him into different climates, and can have their properties or instincts variously diversified by differences of nourishment and habits. If the resources of a species be so limited, and its habits and faculties be of such a confined and local character, that it can only flourish in a few particular spots, it can rarely be of great utility.

* Phil. Zool. tom. i. p. 266.

We may consider, therefore, that, in the domestication of animals and the cultivation of plants, mankind have first selected those species which have the most flexible frames and constitutions, and have then been engaged for ages in conducting a series of experiments, with much patience and at great cost, to ascertain what may be the greatest possible deviation from a common type which can be elicited in these extreme cases.

Varieties of the dog — no transmutation.— The modifications produced in the different races of dogs exhibit the influence of man in the most striking point of view. These animals have been transported into every climate, and placed in every variety of circumstances; they have been made, as a modern naturalist observes, the servant, the companion, the guardian, and the intimate friend of man, and the power of a superior genius has had a wonderful influence, not only on their forms, but on their manners and intelligence.* Different races have undergone remarkable changes in the quantity and colour of their clothing; the dogs of Guinea are almost naked, while those of the arctic circle are covered with a warm coat both of hair and wool, which enables them to bear the most intense cold without inconvenience. There are differences also of another kind no less remarkable, as in size, the length of their muzzles, and the convexity of their foreheads.

But, if we look for some of those essential changes which would be required to lend even the semblance of a foundation for the theory of Lamarck, respecting the growth of new organs and the gradual obliteration

* Dureau de la Malle, Ann. des Sci. Nat. tom. xxi. p. 63. Sept. 1830.

of others, we find nothing of the kind. For, in all these varieties of the dog, says Cuvier, the relation of the bones with each other remains essentially the same; the form of the teeth never changes in any perceptible degree, except that, in some individuals, one additional false grinder occasionally appears, sometimes on the one side, and sometimes on the other.* The greatest departure from a common type — and it constitutes the maximum of variation as yet known in the animal kingdom — is exemplified in those races of dogs which have a supernumerary toe on the hind foot with the corresponding tarsal bones; a variety analogous to one presented by six-fingered families of the human race.†

Lamarck has thrown out as a conjecture, that the wolf may have been the original of the dog; and eminent naturalists are still divided in opinion on this subject. It seems now admitted that both species agree in the period of gestation, and Mr. Owen has been unable to confirm the alleged difference in the structure of a part of the intestinal canal.‡ Mr. Bell inclines to the opinion that all the various races of dogs have descended from one common stock, of which the wolf is the original source.§

It is well known that the horse, the ox, the boar, and other domestic animals, which have been introduced into South America, and have run wild in many parts, have entirely lost all marks of domesticity, and have reverted to the original characters of their species. But dogs have also become wild in Cuba,

* Disc. Prél. p. 129. sixth edition. † Ibid.

‡ Güldenstädt, cited by Prichard, Phys. Hist. of Mankind, vol. i. p. 96.

§ History of British Quadrupeds, p. 200. 1837.

Hayti, and in all the Caribbean islands. In the course of the seventeenth century, they hunted in packs from twelve to fifty, or more, in number, and fearlessly attacked herds of wild boars and other animals. It is natural, therefore, to inquire to what form they reverted? Now, they are said by many travellers to have resembled very nearly the shepherd's dog; but it is certain that they were never turned into wolves. They were extremely savage, and their ravages appear to have been as much dreaded as those of wolves; but when any of their whelps were caught, and brought from the woods to the towns, they grew up in the most perfect submission to man.

Many examples might be adduced to prove that the extent to which the alteration of species can be pushed in the domestic state depends on the original capacity of the species to admit of variation. The horse has been as long domesticated as the dog, yet its different races depart much less widely from a common type; the ass has been still less changed, the camel scarcely at all, yet these species have probably been subjected to the influence of domestication as long as the horse.

Mummies of animals in Egyptian tombs identical with species still living. — As the advocates of the theory of transmutation trust much to the slow and insensible changes which time may work, they are accustomed to lament the absence of accurate descriptions, and figures of particular animals and plants, handed down from the earliest periods of history, such as might have afforded data for comparing the condition of species, at two periods considerably remote. But, fortunately, we are in some measure independent of such evidence: for, by a singular accident, the priests of Egypt have bequeathed to us, in their cemeteries,

that information which the museums and works of the Greek philosophers have failed to transmit.

For the careful investigation of these documents, we are greatly indebted to the skill and diligence of those naturalists who accompanied the French armies during their brief occupation of Egypt: that conquest of four years, from which we may date the improvement of the modern Egyptians in the arts and sciences, and the rapid progress which has been made of late in our knowledge of the arts and sciences of their remote predecessors. Instead of wasting their whole time, as so many preceding travellers had done, in exclusively collecting human mummies, M. Geoffroy and his associates examined diligently, and sent home great numbers of embalmed bodies of consecrated animals, such as the bull, the dog, the cat, the ape, the ichneumon, the crocodile, and the ibis.

To those who have never been accustomed to connect the facts of Natural History with philosophical speculations, who have never raised their conceptions of the end and import of such studies beyond the mere admiration of isolated and beautiful objects, or the exertion of skill in detecting specific differences, it will seem incredible that amidst the din of arms, and the stirring excitement of political movements, so much enthusiasm could have been felt in regard to these precious remains.

In the official report, drawn up by the Professors of the Museum at Paris, on the value of these objects, there are some eloquent passages, which may appear extravagant, unless we reflect how fully these naturalists could appreciate the bearing of the facts thus brought to light on the past history of the globe.

"It seems," say they, "as if the superstition of the

ancient Egyptians had been inspired by Nature, with a view of transmitting to after ages a monument of her history. That extraordinary and whimsical people, by embalming with so much care the brutes which were the objects of their stupid adoration, have left us, in their sacred grottos, cabinets of zoology almost complete. The climate has conspired with the art of embalming to preserve the bodies from corruption, and we can now assure ourselves by our own eyes what was the state of a great number of species three thousand years ago. We can scarcely restrain the transports of our imagination, on beholding thus preserved, with their minutest bones, with the smallest portions of their skin, and in every particular most perfectly recognizable, many an animal, which at Thebes or Memphis, two or three thousand years ago, had its own priests and altars." *

Among the Egyptian mummies thus procured were not only those of numerous wild quadrupeds, birds, and reptiles; but, what was perhaps of still higher importance in deciding the great question under discussion, there were the mummies of domestic animals, among which those above mentioned, the bull, the dog, and the cat, were frequent. Now, such was the conformity of the whole of these species to those now living, that there was no more difference, says Cuvier, between them than between the human mummies and the embalmed bodies of men of the present day. Yet some of these animals have since that period been transported by man to almost every climate, and forced to accommodate their habits to the greatest variety of circumstances. The cat, for example, has been carried

* Ann. du Muséum d'Hist. Nat. tom. i. p. 234. 1802. The reporters were MM. Cuvier, Lacépède, and Lamarck.

over the whole earth, and, within the last three centuries, has been naturalized in every part of the new world, — from the cold regions of Canada to the tropical plains of Guiana; yet it has scarcely undergone any perceptible mutation, and is still the same animal which was held sacred by the Egyptians.

Of the ox, undoubtedly, there are many very distinct races: but the bull Apis, which was led in solemn processions by the Egyptian priests, did not differ from some of those now living. The black cattle that have run wild in America, where there were many peculiarities in the climate not to be found, perhaps, in any part of the old world, and where scarcely a single plant on which they fed was of precisely the same species, instead of altering their form and habits, have actually reverted to the exact likeness of the aboriginal wild cattle of Europe.

In answer to the arguments drawn from the Egyptian mummies, Lamarck said that they were identical with their living descendants in the same country, because the climate and physical geography of the banks of the Nile have remained unaltered for the last thirty centuries. But why, it may be asked, have other individuals of these species retained the same characters in so many different quarters of the globe, where the climate and many other conditions are so varied?

Seeds and plants from the Egyptian tombs. — The evidence derived from the Egyptian monuments was not confined to the animal kingdom; the fruits, seeds, and other portions of twenty different plants, were faithfully preserved in the same manner; and among these the common wheat was procured by Delille, from closed vessels in the sepulchres of the kings, the grains of which retained not only their form, but even

their colour; so effectual has proved the process of embalming with bitumen in a dry and equable climate. No difference could be detected between this wheat and that which now grows in the East and elsewhere, and similar identifications were made in regard to all the other plants.

Native country of the common wheat. — And here I may observe, that there is an obvious answer to Lamarck's objection, that the botanist cannot point out a country where the common wheat grows wild, unless in places where it may have been derived from neighbouring cultivation.* All naturalists are well aware that the geographical distribution of a great number of species is extremely limited; that it was to be expected that every useful plant should first be cultivated successfully in the country where it was indigenous; and that, probably every station which it partially occupied, when growing wild, would be selected by the agriculturist as best suited to it when artificially increased. Palestine has been conjectured, by a late writer on the Cerealia, to have been the original habitation of wheat and barley; a supposition which appears confirmed by Hebrew and Egyptian traditions, and by tracing the migrations of the worship of Ceres, as indicative of the migrations of the plant.†

If we are to infer that some one of the wild grasses has been transformed into the common wheat, and that some animal of the genus *canis*, still unreclaimed, has been metamorphosed into the dog, merely because we cannot find the domestic dog, or the cultivated wheat, in a state of nature, we may be next called upon to

* Phil. Zool. tom. i. p. 227.

† L'Origine et la Patrie des Céréales, &c., Ann. des Sci. Nat. tom. ix. p. 61.

make similar admissions in regard to the camel; for it seems very doubtful whether any race of this species of quadruped is now wild.

Changes in plants produced by cultivation. — But if agriculture, it will be said, does not supply examples of extraordinary changes of form and organization, the horticulturist can, at least, appeal to facts which may confound the preceding train of reasoning. The crab has been transformed into the apple; the sloe into the plum: flowers have changed their colour, and become double; and these new characters can be perpetuated by seed: a bitter plant, with wavy sea-green leaves, has been taken from the sea-side, where it grew like wild charlock; has been transplanted into the garden, lost its saltness, and has been metamorphosed into two distinct vegetables, as unlike each other as is each to the parent plant — the red cabbage and the cauliflower. These, and a multitude of analogous facts, are undoubtedly among the wonders of nature, and attest more strongly, perhaps, the extent to which species may be modified, than any examples derived from the animal kingdom. But in these cases we find that we soon reach certain limits, beyond which we are unable to cause the individuals descending from the same stock to vary; while, on the other hand, it is easy to show that these extraordinary varieties could seldom arise, and could never be perpetuated in a wild state for many generations, under any imaginable combination of accidents. They may be regarded as extreme cases, brought about by human interference, and not as phenomena which indicate a capability of indefinite modification in the natural world.

The propagation of a plant by buds or grafts, and by cuttings, is obviously a mode which nature does

not employ; and this multiplication, as well as that produced by roots and layers, seems merely to operate as an extension of the life of an individual, and not as a reproduction of the species such as happens by seed. All plants increased by grafts or layers retain precisely the peculiar qualities of the individual to which they owe their origin, and, like an individual, they have only a determinate existence; in some cases longer, and in others shorter.* It seems now admitted by horticulturists, that none of our garden varieties of fruit are entitled to be considered strictly permanent, but that they wear out after a time†; and we are thus compelled to resort again to seeds: in which case there is so decided a tendency in the seedlings to revert to the original type, that our utmost skill is sometimes baffled in attempting to recover the desired variety.

Varieties of the cabbage.—The different races of cabbages afford, as was admitted, an astonishing example of deviation from a common type; but we can scarcely conceive them to have originated, much less to have lasted for several generations, without the intervention of man. It is only by strong manures that these varieties have been obtained, and in poorer soils they instantly degenerate. If, therefore, we suppose in a state of nature the seed of the wild *Brassica oleracea* to have been wafted from the sea-side to some spot enriched by the dung of animals, and to have there become a cauliflower, it would soon diffuse its seed to some comparatively sterile soils around, and the offspring would relapse to the likeness of the parent stock.

* Smith's Introduction to Botany, p. 138. Edit. 1807.

† See Mr. Knight's Observations, Hort. Trans. vol. ii. p. 160.

But if we go so far as to imagine the soil, in the spot first occupied, to be constantly manured by herds of wild animals, so as to continue as rich as that of a garden, still the variety could not be maintained; because we know that each of these races is prone to fecundate others, and gardeners are compelled to exert the utmost diligence to prevent cross-breeds. The intermixture of the pollen of varieties growing in the poorer soil around would soon destroy the peculiar characters of the race which occupied the highly manured tract; for, if these accidents so continually happen, in spite of our care, among the culinary varieties, it is easy to see how soon this cause might obliterate every marked singularity in a wild state.

Besides, it is well known that, although the pampered races which we rear in our gardens for use or ornament may often be perpetuated by seed, yet they rarely produce seed in such abundance, or so prolific in quality, as wild individuals; so that if the care of man were withdrawn, the most fertile variety would always, in the end, prevail over the more sterile.

Similar remarks may be applied to the double flowers, which present such strange anomalies to the botanist. The ovarium, in such cases, is frequently abortive; and the seeds, when prolific, are generally much fewer than where the flowers are single.

Changes caused by soil.—Some curious experiments, recently made on the production of blue instead of red flowers in the *Hydrangea hortensis*, illustrate the immediate effect of certain soils on the colours of the calyx and petals. In garden-mould or compost, the flowers are invariably red; in some kinds of bog-earth they are blue; and the same change is always produced by a particular sort of yellow loam.

Varieties of the primrose. — Linnæus was of opinion that the primrose, oxlip, cowslip, and polyanthus, were only varieties of the same species. The majority of modern botanists, on the contrary, consider them to be distinct, although some conceived that the oxlip might be a cross between the cowslip and the primrose. Mr. Herbert has lately recorded the following experiment: — "I raised from the natural seed of one umbel of a highly manured red cowslip a primrose, a cowslip, oxlips of the usual and other colours, a black polyanthus, a hose-in-hose cowslip, and a natural primrose bearing its flower on a polyanthus stock. From the seed of that very hose-in-hose cowslip, I have since raised a hose-in-hose primrose. I therefore consider all these to be only local varieties, depending upon soil and situation." * Professor Henslow, of Cambridge, has since confirmed this experiment of Mr. Herbert; so that we have an example, not only of the remarkable varieties which the florist can obtain from a common stock, but of the distinctness of analogous races found in a wild state.†

On what particular ingredient, or quality in the earth, these changes depend, has not yet been ascertained.‡ But gardeners are well aware that particular plants, when placed under the influence of certain circumstances, are changed in various ways, according to the species; and as often as the experiments are repeated, similar results are obtained. The nature of these results, however, depends upon the species, and they are, therefore, part of the specific character; they exhibit the same phenomena again and again, and

* Hort. Trans. vol. iv. p. 19.

† Loudon's Mag. of Nat. Hist. Sept. 1830, vol. iii. p. 408.

‡ Hort. Trans. vol. iii. p. 173.

indicate certain fixed and invariable relations between the physiological peculiarities of the plant, and the influence of certain external agents. They afford no ground for questioning the instability of species, but rather the contrary: they present us with a class of phenomena which, when they are more thoroughly understood, may afford some of the best tests for identifying species, and proving that the attributes originally conferred endure so long as any issue of the original stock remains upon the earth.

CHAPTER III.

WHETHER SPECIES HAVE A REAL EXISTENCE IN NATURE — *continued.*

Limits of the variability of species — Species susceptible of modification may be altered greatly in a short time, and in a few generations; after which they remain stationary — The animals now subject to man had originally an aptitude to domesticity — Acquired peculiarities which become hereditary have a close connexion with the habits or instincts of the species in a wild state — Some qualities in certain animals have been conferred with a view of their relation to man — Wild elephant domesticated in a few years, but his faculties incapable of further development.

Variability of a species compared to that of an individual.— I ENDEAVOURED, in the last chapter, to show, that a belief in the reality of species is not inconsistent with the idea of a considerable degree of variability in the specific character. This opinion, indeed, is little more than an extension of the idea which we must entertain of the identity of an individual, throughout the changes which it is capable of undergoing.

If a quadruped, inhabiting a cold northern latitude, and covered with a warm coat of hair or wool, be transported to a southern climate, it will often in the course of a few years, shed a considerable portion of its coat, which it gradually recovers on being again

restored to its native country. Even there the same changes are, perhaps, superinduced to a certain extent by the return of winter and summer. We know that the Alpine hare (*Lepus variabilis*, Pal.) and the ermine, or stoat (*Mustela erminea*, Linn.) become white during winter, and again obtain their full colour during the warmer season; that the plumage of the ptarmigan undergoes a like metamorphosis in colour and quantity, and that the change is equally temporary. We are aware that, if we reclaim some wild animal, and modify its habits and instincts by domestication, it may, if it escapes, become in a few years nearly as wild and untractable as ever; and if the same individual be again retaken, it may be reduced to its former tame state. A plant is placed in a prepared soil, in order that the petals of its flowers may multiply, and their colour be heightened or changed; if we then withhold our care, the flowers of this same individual become again single. In these, and innumerable other instances, we must suppose that the individual was produced with a certain number of qualities; and, in the case of animals, with a variety of instincts, some of which may or may not be developed according to circumstances, or which, after having been called forth, may again become latent when the exciting causes are removed.

Now, the formation of races seems the necessary consequence of such a capability in individuals to vary, if it be a general law that the offspring should very closely resemble the parent. But, before we can infer that there are no limits to the deviation from an original type which may be brought about in the course of an indefinite number of generations, we ought to have some proof that, in each successive generation,

individuals may go on acquiring an equal amount of new peculiarities, under the influence of equal changes of circumstances. The balance of evidence, however, inclines most decidedly on the opposite side; for in all cases we find that the quantity of divergence diminishes from the first in a very rapid ratio.

Species susceptible of modification may be greatly altered in a few generations.—It cannot be objected, that it is out of our power to go on varying the circumstances in the same manner as might happen in the natural course of events during some great geological cycle. For in the first place, where a capacity is given to individuals to adapt themselves to new circumstances, it does not generally require a very long period for its development; if, indeed, such were the case, it is not easy to see how the modification would answer the ends proposed, for all the individuals would die before new qualities, habits, or instincts were conferred.

When we have succeeded in naturalizing some tropical plant in a temperate climate, nothing prevents us from attempting gradually to extend its distribution to higher latitudes, or to greater elevations above the level of the sea, allowing equal quantities of time, or an equal number of generations, for habituating the species to successive increments of cold. But every husbandman and gardener is aware that such experiments will fail; and we are more likely to succeed in making some plants, in the course of the first two generations, support a considerable degree of difference of temperature than a very small difference afterwards, though we persevere for many centuries.

It is the same if we take any other cause instead of temperature; such as the quality of the food, or the

kind of dangers to which an animal is exposed, or the soil in which a plant lives. The alteration in habits, form, or organization, is often rapid during a short period; but when the circumstances are made to vary further, though in ever so slight a degree, all modification ceases, and the individual perishes. Thus some herbivorous quadrupeds may be made to feed partially on fish or flesh; but even these can never be taught to live on some herbs which they reject, and which would even poison them, although the same may be very nutritious to other species of the same natural order. So, when man uses force or stratagem against wild animals, the persecuted race soon becomes more cautious, watchful, and cunning; new instincts seem often to be developed, and to become hereditary in the first two or three generations: but let the skill and address of man increase, however gradually, no further variation can take place, no new qualities are elicited by the increasing dangers. The alteration of the habits of the species has reached a point beyond which no ulterior modification is possible, however indefinite the lapse of ages during which the new circumstances operate. Extirpation then follows, rather than such a transformation as could alone enable the species to perpetuate itself under the new state of things.

Animals now subject to man had originally an aptitude to domesticity.— It has been well observed by M. F. Cuvier and M. Dureau de la Malle, that, unless some animals had manifested in a wild state an aptitude to second the efforts of man, their domestication would never have been attempted. If they had all resembled the wolf, the fox, and the hyæna, the patience of the experimentalist would have been exhausted by innumerable failures before he at last succeeded in obtain-

ing some imperfect results; so, if the first advantages derived from the cultivation of plants had been elicited by as tedious and costly a process as that by which we now make some slight additional improvement in certain races, we should have remained to this day in ignorance of the greater number of their useful qualities.

Acquired instincts of some animals become hereditary.—It is undoubtedly true, that many new habits and qualities have not only been acquired in recent times by certain races of dogs, but have been transmitted to their offspring. But in these cases it will be observed, that the new peculiarities have an intimate relation to the habits of the animal in a wild state, and therefore do not attest any tendency to departure to an indefinite extent from the original type of the species. A race of dogs employed for hunting deer in the platform of Santa Fé, in Mexico, affords a beautiful illustration of a new hereditary instinct. The mode of attack, observes M. Roulin, which they employ, consists in seizing the animal by the belly and overturning it by a sudden effort, taking advantage of the moment when the body of the deer rests only upon the fore-legs. The weight of the animal thus thrown over is often six times that of its antagonist. The dog of pure breed inherits a disposition to this kind of chase, and never attacks a deer from before while running. Even should the deer, not perceiving him, come directly upon him, the dog steps aside and makes his assault on the flank; whereas other hunting dogs, though of superior strength, and general sagacity, which are brought from Europe, are destitute of this instinct. For want of similar precautions, they are often killed by the deer on the spot, the vertebræ

of their neck being dislocated by the violence of the shock.*

A new instinct has also become hereditary in a mongrel race of dogs employed by the inhabitants of the banks of the Magdalena almost exclusively in hunting the white-lipped pecari. The address of these dogs consists in restraining their ardour, and attaching themselves to no animal in particular, but keeping the whole herd in check. Now, among these dogs some are found, which, the very first time they are taken to the woods, are acquainted with this mode of attack; whereas, a dog of another breed starts forward at once, is surrounded by the pecari, and, whatever may be his strength, is destroyed in a moment.

Some of our countrymen, engaged of late in conducting one of the principal mining associations in Mexico, that of Real del Monte, carried out with them some English greyhounds of the best breed, to hunt the hares which abound in that country. The great platform which is the scene of sport is at an elevation of about nine thousand feet above the level of the sea, and the mercury in the barometer stands habitually at the height of about nineteen inches. It was found that the greyhounds could not support the fatigues of a long chase in this attenuated atmosphere, and before they could come up with their prey, they lay down gasping for breath; but these same animals have produced whelps which have grown up, and are not in the least degree incommoded by the want of density in the air, but run down the hares with as much ease as the fleetest of their race in this country.

* M. Roulin, Ann. des Sci. Nat. tom. xvi. p. 16. 1829.

The fixed and deliberate stand of the pointer has with propriety been regarded as a mere modification of a habit, which may have been useful to a wild race accustomed to wind game, and steal upon it by surprise, first pausing for an instant, in order to spring with unerring aim. The faculty of the Retriever, however, may justly be regarded as more inexplicable and less easily referrible to the instinctive passions of the species. M. Majendie, says a French writer in a recently published memoir, having learnt that there was a race of dogs in England which stopped and brought back game of their own accord, procured a pair, and, having obtained a whelp from them, kept it constantly under his eyes, until he had an opportunity of assuring himself that, without having received any instruction, and on the very first day that it was carried to the chase, it brought back game with as much steadiness as dogs which had been schooled into the same manœuvre by means of the whip and collar.

Attributes of animals in their relation to man.— Such attainments, as well as the habits and dispositions which the shepherd's dog and many others inherit, seem to be of a nature and extent which we can hardly explain by supposing them to be modifications of instincts necessary for the preservation of the species in a wild state. When such remarkable habits appear in races of this species, we may reasonably conjecture that they were given with no other view than for the use of man and the preservation of the dog, which thus obtains protection.

As a general rule, I fully agree with M. F. Cuvier, that, in studying the habits of animals, we must attempt, as far as possible, to refer their domestic qualities to modifications of instincts which are implanted

in them in a state of nature; and that writer has successfully pointed out, in an admirable essay on the domestication of the mammalia, the true origin of many dispositions which are vulgarly attributed to the influence of education alone.* But we should go too far if we did not admit that some of the qualities of particular animals and plants may have been given solely with a view to the connexion which it was foreseen would exist between them and man—especially when we see that connexion to be in many cases so intimate, that the greater number, and sometimes, as in the case of the camel, all the individuals of the species which exist on the earth are in subjection to the human race.

We can perceive in a multitude of animals, especially in some of the parasitic tribes, that certain instincts and organs are conferred for the purpose of defence or attack against some other species. Now, if we are reluctant to suppose the existence of similar relations between man and the instincts of many of the inferior animals, we adopt an hypothesis no less violent, though in the opposite extreme to that which has led some to imagine the whole animate and inanimate creation to have been made solely for the support, gratification, and instruction of mankind.

Many species, most hostile to our persons or property, multiply, in spite of our efforts to repress them; others, on the contrary, are intentionally augmented many hundred fold in number by our exertions. In such instances, we must imagine the relative resources of man and of species, friendly or inimical to him, to have been prospectively calculated and adjusted. To

* Mém. du Mus. d'Hist. Nat.—Jameson, Ed. New Phil. Journ., Nos. 6, 7, 8.

withhold assent to this supposition, would be to refuse what we must grant in respect to the economy of Nature in every other part of the organic creation; for the various species of contemporary plants and animals have obviously their relative forces nicely balanced, and their respective tastes, passions, and instincts so contrived, that they are all in perfect harmony with each other. In no other manner could it happen that each species, surrounded, as it is, by countless dangers, should be enabled to maintain its ground for periods of considerable duration.

The docility of the individuals of some of our domestic species, extending, as it does, to attainments foreign to their natural habits and faculties, may, perhaps, have been conferred with a view to their association with man. But, lest species should be thereby made to vary indefinitely, we find that such habits are never transmissible by generation.

A pig has been trained to hunt and point game with great activity and steadiness;* and other learned individuals, of the same species, have been taught to spell; but such fortuitous acquirements never become hereditary, for they have no relation whatever to the exigencies of the animal in a wild state, and cannot, therefore, be developments of any instinctive propensities.

Influence of domestication. — An animal in domesticity, says M. F. Cuvier, is not essentially in a different situation, in regard to the feeling of restraint, from one left to itself. It lives in society without constraint, because, without doubt, it was a social animal; and it

* In the New Forest, near Ringwood, Hants, by Mr. Toomer, keeper of Broomy Lodge. I have conversed with witnesses of the fact.

conforms itself to the will of man, because it had a chief, to which, in a wild state, it would have yielded obedience. There is nothing in its new situation that is not conformable to its propensities; it is satisfying its wants by submission to a master, and makes no sacrifice of its natural inclinations. All the social animals, when left to themselves, form herds more or less numerous; and all the individuals of the same herd know each other, are mutually attached, and will not allow a strange individual to join them. In a wild state, moreover, they obey some individual, which, by its superiority, has become the chief of the herd. Our domestic species had, originally, this sociability of disposition; and no solitary species, however easy it may be *to tame it*, has yet afforded true domestic races. We merely, therefore, develope, to our own advantage, propensities which propel the individuals of certain species to draw near to their fellows.

The sheep which we have reared is induced to follow us, as it would be led to follow the flock among which it was brought up; and, when individuals of gregarious species have been accustomed to one master, it is he alone whom they acknowledge as their chief — he only whom they obey. "The elephant allows himself to be directed only by the carnac whom he has adopted; the dog itself, reared in solitude with its master, manifests a hostile disposition towards all others; and every body knows how dangerous it is to be in the midst of a herd of cows, in pasturages that are little frequented, when they have not at their head the keeper who takes care of them.

"Every thing, therefore, tends to convince us, that formerly men were only, with regard to the domestic animals, what those who are particularly charged with

the care of them still are — namely, members of the society which these animals form among themselves; and that they are only distinguished, in the general mass by the authority which they have been enabled to assume from their superiority of intellect. Thus, every social animal which recognizes man as a member, and as the chief of its herd, is a domestic animal. It might even be said, that, from the moment when such an animal admits man as a member of its society, it is domesticated, as man could not enter into such a society without becoming the chief of it." *

But the ingenious author whose observations I have here cited, admits that the obedience which the individuals of many domestic species yield indifferently to every person, is without analogy in any state of things which could exist previously to their subjugation by man. Each troop of wild horses, it is true, has some stallion for its chief, who draws after him all the individuals of which the herd is composed; but, when a domesticated horse has passed from hand to hand, and has served several masters, he becomes equally docile towards *any person*, and is subjected to the whole human race. It seems fair to presume that the capability in the instinct of the horse to be thus modified, was given to enable the species to render greater services to man; and, perhaps, the facility with which many other acquired characters become hereditary in various races of the horse, may be explicable only on a like supposition. The amble, for example, a pace to which the domestic races in some parts of Spanish America are exclusively trained, has, in the course of several generations, become hereditary, and

* Mém. du Mus. d'Hist. Nat.

is assumed by all the young colts before they are broken in.*

It seems, also, reasonable to conclude, that the power bestowed on the horse, the dog, the ox, the sheep, the cat, and many species of domestic fowls, of supporting almost every climate, was given expressly to enable them to follow man throughout all parts of the globe, in order that we might obtain their services, and they our protection. If it be objected that the elephant, which by the union of strength, intelligence, and docility, can render the greatest services to mankind, is incapable of living in any but the warmest latitudes, we may observe, that the quantity of vegetable food required by this quadruped would render its maintenance in the temperate zone too costly, and in the arctic impossible.

Among the changes superinduced by man, none appear, at first sight, more remarkable than the perfect tameness of certain domestic races. It is well known that, at however early an age we obtain possession of the young of many unreclaimed races, they will retain, throughout life, a considerable timidity and apprehensiveness of danger; whereas, after one or two generations, the descendants of the same stock will habitually place the most implicit confidence in man. There is good reason, however, to suspect that such changes are not without analogy in a state of nature; or, to speak more correctly, in situations where man has not interfered.

We learn from Mr. Darwin, that in the Galapagos archipelago, placed directly under the equator, and nearly 600 miles west of the American continent, that

* Dureau de la Malle, Ann. des Sci. Nat. tom. xxi. p. 58.

all the terrestrial birds, as the finches, doves, hawks, and others, are so tame, that they may be killed with a switch. One day, says this author, "a mocking-bird alighted on the edge of a pitcher which I held in my hand, and began quietly to sip the water, and allowed me to lift it with the vessel from the ground." Yet formerly, when the first Europeans landed, and found no inhabitants in these islands, the birds were even tamer than now; already they are beginning to acquire that salutary dread of man which in countries long settled is natural even to young birds, which have never received any injury. So in the Falkland Islands, both the birds and foxes are entirely without fear of man; whereas, in the adjoining mainland of South America, many of the same species of birds are extremely wild; for there they have for ages been persecuted by the natives.*

Dr. Richardson informs us, in his able history of the habits of the North American animals, that, "in the retired parts of the mountains, where the hunters had seldom penetrated, there is no difficulty in approaching the Rocky Mountain sheep, which there exhibit *the simplicity of character so remarkable in the domestic species;* but where they have been often fired at, they are exceedingly wild, alarm their companions, on the approach of danger, by a hissing noise, and scale the rocks with a speed and agility that baffle pursuit." †

It is probable, therefore, that as man, in diffusing himself over the globe, has tamed many wild races, so, also, he has made many tame races wild. Had some of the larger carnivorous beasts, capable of scaling the

* Darwin's Journ. in Voyage of H. M. S. Beagle, p. 475.

† Fauna Boreali-Americana, p. 273.

rocks, made their way into the North American mountains before our hunters, a similar alteration in the instincts of the sheep would doubtless have been brought about.

Wild elephants domesticated in a few years. — No animal affords a more striking illustration of the principal points which I have been endeavouring to establish than the elephant; for, in the first place, the wonderful sagacity with which he accommodates himself to the society of man, and the new habits which he contracts, are not the result of time, nor of modifications produced in the course of many generations. These animals will breed in captivity, as is now ascertained, in opposition to the vulgar opinion of many modern naturalists, and in conformity to that of the ancients Ælian and Columella *: yet it has always been the custom, as the least expensive mode of obtaining them, to capture wild individuals in the forests, usually when full grown; and, in a few years after they are taken — sometimes, it is said, in the space of a few months — their education is completed.

Had the whole species been domesticated from an early period in the history of man, like the camel, their superior intelligence would, doubtless have been attributed to their long and familiar intercourse with the lord of the creation; but we know that a few years is sufficient to bring about this wonderful change of habits; and, although the same individual may continue to receive tuition for a century afterwards, yet it makes no further progress in the general development of its faculties. Were it otherwise, indeed, the

* Mr. Corse on the Habits, &c. of the Elephant, Phil. Trans. 1799.

animal would soon deserve more than the poet's epithet of "half-reasoning."

From the authority of our countrymen employed in the late Burmese war, it appears, in corroboration of older accounts, that, when elephants are required to execute extraordinary tasks, they may be made to understand that they will receive unusual rewards. Some favourite dainty is shown to them, in the hope of acquiring which the work is done; and so perfectly does the nature of the contract appear to be understood, that the breach of it, on the part of the master, is often attended with danger. In this case, a power has been given to the species to adapt their social instincts to new circumstances with surprising rapidity; but the extent of this change is defined by strict and arbitrary limits. There is no indication of a tendency to continued divergence from certain attributes with which the elephant was originally endued — no ground whatever for anticipating that, in thousands of centuries, any material alteration could ever be effected. All that we can infer from analogy is, that some more useful and peculiar races might probably be formed, if the experiment were fairly tried; and that some individual characteristic, now only casual and temporary, might be perpetuated by generation.

In all cases, therefore, where the domestic qualities exist in animals, they seem to require no lengthened process for their development; and they appear to have been wholly denied to some classes, which, from their strength and social disposition, might have rendered great services to man; as, for example, the greater part of the quadrumana. The orang-outang, indeed, which, for its resemblance in form to man, and apparently for no other good reason, has been

assumed by Lamarck to be the most perfect of the inferior animals, has been tamed by the savages of Borneo, and made to climb lofty trees, and to bring down the fruit. But he is said to yield to his masters an unwilling obedience, and to be held in subjection only by severe discipline. We know nothing of the faculties of this animal which can suggest the idea that it rivals the elephant in intelligence; much less any thing which can countenance the dreams of those who have fancied that it might have been transmuted into "the dominant race." One of the baboons of Sumatra (*Simia carpolegus*) appears to be more docile, and is frequently trained by the inhabitants to ascend trees, for the purpose of gathering cocoa-nuts; a service in which the animal is very expert. He selects, says Sir Stamford Raffles, the ripe nuts, with great judgment, and pulls no more than he is ordered.* The capuchin and cacajao monkeys are, according to Humboldt, taught to ascend trees in the same manner, and to throw down fruit on the banks of the lower Orinoco.†

It is for the Lamarckians to explain how it happens that those same savages of Borneo have not themselves acquired, by dint of longing, for many generations, for the power of climbing trees, the elongated arms of the orang, or even the prehensile tails of some American monkeys. Instead of being reduced to the necessity of subjugating stubborn and untractable brutes, we should naturally have anticipated "that their wants would have excited them to efforts, and that continued efforts would have given rise to new organs;" or, rather

* Linn. Trans. vol. xiii. p. 244.

† Pers. Narr. of Travels to the Equinoctial Regions of the New Continent, in the years 1779—1804.

to the re-acquisition of organs which, in a manner irreconcileable with the principle of the *progressive* system, have grown obsolete in tribes of men which have such constant need of them.

Recapitulation.— It follows, then, from the different facts which have been considered in this chapter, that a short period of time is generally sufficient to effect nearly the whole change which an alteration of external circumstances can bring about in the habits of a species, and that such capacity of accommodation to new circumstances is enjoyed, in very different degrees, by different species.

Certain qualities appear to be bestowed exclusively with a view to the relations which are destined to exist between different species and, among others, between certain species and man; but these latter are always so nearly connected with the original habits and propensities of each species in a wild state, that they imply no indefinite capacity of varying from the original type. The acquired habits derived from human tuition are rarely transmitted to the offspring; and when this happens, it is almost universally the case with those merely which have some obvious connexion with the attributes of the species when in a state of independence.

CHAPTER IV.

WHETHER SPECIES HAVE A REAL EXISTENCE IN NATURE — *continued.*

Phenomena of hybrids — Hunter's opinions — Mules not strictly intermediate between parent species — Hybrid plants — Experiments of Kölreuter and Wiegmann — Vegetable hybrids prolific throughout several generations — Why rare in a wild state — De Candolle on hybrid plants — The phenomena of hybrids confirm the distinctness of species — Theory of the gradation in the intelligence of animals as indicated by the facial angle — Tiedemann on the brain of the fœtus in mammalia assuming successively the form of the brain of fish, reptile, and bird — Bearing of this discovery on the theory of progressive development and transmutation — Recapitulation.

Phenomena of hybrids.— We have yet to consider another class of phenomena, those relating to the production of hybrids, which have been regarded in a very different light with reference to their bearing on the question of the permanent distinctness of species; some naturalists considering them as affording the strongest of all proofs in favour of the reality of species; others, on the contrary, appealing to them as countenancing the opposite doctrine, that all the varieties of organization and instinct now exhibited in the animal and vegetable kingdoms may have been propagated from a small number of original types.

In regard to the mammifers and birds, it is found that no sexual union will take place between races which are remote from each other in their habits and organization; and it is only in species that are very nearly allied that such unions produce offspring. It may be laid down as a general rule, admitting of very few exceptions among quadrupeds, that the hybrid progeny is sterile; and there seem to be no well-authenticated examples of the continuance of the mule race beyond one generation. The principal number of observations and experiments relate to the mixed offspring of the horse and the ass; and in this case it is well established that the he-mule can generate, and the she-mule produce. Such cases occur in Spain and Italy, and much more frequently in the West Indies and New Holland; but these mules have never bred in cold climates, seldom in warm regions, and still more rarely in temperate countries.

The hybrid offspring of the she-ass and the stallion, the γιννος of Aristotle, and the hinnus of Pliny, differs from the mule, or the offspring of the ass and mare. In both cases, says Buffon, these animals retain more of the dam than of the sire, not only in the magnitude, but in the figure of the body; whereas, in the form of the head, limbs, and tail, they bear a greater resemblance to the sire. The same naturalist infers, from various experiments respecting cross-breeds between the he-goat and ewe, the dog and she-wolf, the goldfinch and canary-bird, that the male transmits his sex to the greatest number, and that the preponderance of males over females exceeds that which prevails where the parents are of the same species.

Hunter's opinion.—The celebrated John Hunter has observed, that the true distinction of species must

ultimately be gathered from their incapacity of propagating with each other, and producing offspring capable of again continuing itself. He was unwilling, however, to admit that the horse and the ass were of the same species, because some rare instances had been adduced of the breeding of mules, although he maintained that the wolf, the dog, and the jackal were all of one species; because he had found, by two experiments, that the dog would breed both with the wolf and the jackal; and that the mule, in each case, would breed again with the dog. In these cases, however, it may be observed, that there was always one parent at least of pure breed, and no proof was obtained that a true hybrid race could be perpetuated; a fact of which I believe no examples are yet recorded, either in regard to mixtures of the horse and ass, or any other of the mammalia.

Should the fact be hereafter ascertained, that two mules can propagate their kind, we must still inquire whether the offspring may not be regarded in the light of a monstrous birth, proceeding from some accidental cause, or, rather, to speak more philosophically, from some general law not yet understood, but which may not be permitted permanently to interfere with those laws of generation by which species may, in general, be prevented from becoming blended. If, for example, we discovered that the progeny of a mule race degenerated greatly, in the first generation, in force, sagacity, or any attribute necessary for its preservation in a state of nature, we might infer that, like a monster, it is a mere temporary and fortuitous variety. Nor does it seem probable that the greater number of such monsters could ever occur unless obtained by art; for, in Hunter's experiments, stratagem or force

was, in most instances, employed to bring about the irregular connexion.*

Mules not strictly intermediate between the parent species. — It seems rarely to happen that the mule offspring is truly intermediate in character between the two parents. Thus Hunter mentions that, in his experiments, one of the hybrid pups resembled the wolf much more than the rest of the litter; and we are informed by Wiegmann, that, in a litter lately obtained in the Royal Menagerie at Berlin, from a white pointer and a she-wolf, two of the cubs resembled the common wolf-dog, but the third was like a pointer with hanging ears.

There is undoubtedly a very close analogy between these phenomena and those presented by the intermixture of distinct races of the same species, both in the inferior animals and in man. Dr. Prichard, in his "Physical History of Mankind," cites examples where the peculiarities of the parents have been transmitted very unequally to the offspring; as where children, entirely white, or perfectly black, have sprung from the union of the European and the negro. Sometimes the colour or other peculiarities of one parent, after having failed to show themselves in the immediate progeny, reappear in a subsequent generation; as where a white child is born of two black parents, the grandfather having been a white.†

The same author judiciously observes that, if different species mixed their breed, and hybrid races were often propagated, the animal world would soon present a scene of confusion; its tribes would be

* Phil. Trans. 1787. Additional Remarks, Phil. Trans. 1789.

† Prichard, vol. i. p. 217.

everywhere blended together, and we should perhaps find more hybrid creatures than genuine and uncorrupted races.*

Hybrid plants — Kölreuter's experiments. — The history of the vegetable kingdom has been thought to afford more decisive evidence in favour of the theory of the formation of new and permanent species from hybrid stocks. The first accurate experiments in illustration of this curious subject appear to have been made by Kölreuter, who obtained a hybrid from two species of tobacco, *Nicotiana rustica* and *N. paniculata*, which differ greatly in the shape of their leaves, the colour of the corolla, and the height of the stem. The stigma of a plant of *N. rustica* was impregnated with the pollen of a plant of *N. paniculata*. The seed ripened, and produced a hybrid which was intermediate between the two parents, and which, like all the hybrids which this botanist brought up, had imperfect stamens. He afterwards impregnated this hybrid with the pollen of *N. paniculata*, and obtained plants which much more resembled the last. This he continued through several generations, until, by due perseverance, he actually changed the *Nicotiana rustica* into the *Nicotiana paniculata*.

The plan of impregnation adopted was the cutting off of the anthers of the plant intended for fructification before they had shed pollen, and then laying on foreign pollen upon the stigma.

Wiegmann's experiments. — The same experiment has since been repeated with success by Wiegmann, who found that he could bring back the hybrids to the exact likeness of either parent, by crossing them a sufficient number of times.

* Prichard, vol. i. p. 97.

The blending of the characters of the parent stocks, in many other of Wiegmann's experiments, was complete; the colour and shape of the leaves and flowers, and even the scent, being intermediate, as in the offspring of the two species of verbascum. An intermarriage, also, between the common onion and the leek (*Allium cepa* and *A. porrum*) gave a mule plant, which, in the character of its leaves and flowers, approached most nearly to the garden onion, but had the elongated bulbous root and smell of the leek.

The same botanist remarks, that vegetable hybrids, when not strictly intermediate, more frequently approach the female than the male parent species, *but they never exhibit characters foreign to both.* A recross with one of the original stocks generally causes the mule plant to revert towards that stock; but this is not always the case, the offspring sometimes continuing to exhibit the character of a full hybrid.

In general, the success attending the production and perpetuity of hybrids among plants depends, as in the animal kingdom, on the degree of proximity between the species intermarried. If their organization be very remote, impregnation never takes place; if somewhat less distant, seeds are formed, but always imperfect and sterile. The next degree of relationship yields hybrid seedlings, but these are barren; and it is only when the parent species are very nearly allied that the hybrid race may be perpetuated for several generations. Even in this case, the best authenticated examples seem confined to the crossing of hybrids with individuals of pure breed. In none of the experiments most accurately detailed does it appear that both the parents were mules.

Wiegmann diversified as much as possible his mode

of bringing about these irregular unions among plants. He often sowed parallel rows, near to each other, of the species from which he desired to breed; and, instead of mutilating, after Kölreuter's fashion, the plants of one of the parent stocks, he merely washed the pollen off their anthers. The branches of the plants in each row were then gently bent towards each other and intertwined; so that the wind, and numerous insects, as they passed from the flowers of one to those of the other species, carried the pollen and produced fecundation.

Vegetable hybrids why rare in a wild state. — The same observer saw a good exemplification of the manner in which hybrids may be formed in a state of nature. Some wallflowers and pinks had been growing in a garden, in a dry sunny situation; and their stigmas had been ripened so as to be moist, and to absorb pollen with avidity, although their anthers were not yet developed. These stigmas became impregnated by pollen blown from some other adjacent plants of the same species; but, had they been of different species, and not too remote in their organization, mule races must have resulted.

When, indeed, we consider how busily some insects have been shown to be engaged in conveying anther-dust from flower to flower, especially bees, flower-eating beetles, and the like, it seems a most enigmatical problem how it can happen that promiscuous alliances between distinct species are not perpetually occurring.

How continually do we observe the bees diligently employed in collecting the red and yellow powder by which the stamens of flowers are covered, loading it on their hind legs, and carrying it to their hive for the

purpose of feeding their young! In thus providing for their own progeny, these insects assist materially the process of fructification.* Few persons need be reminded that the stamens in certain plants grow on different blossoms from the pistils; and, unless the summit of the pistil be touched with the fertilizing dust, the fruit does not swell, nor the seed arrive at maturity. It is by the help of bees, chiefly, that the development of the fruit of many such species is secured, the powder which they have collected from the stamens being unconsciously left by them in visiting the pistils.

How often, during the heat of a summer's day, do we see the males of diœcious plants, such as the yew-tree, standing separate from the females, and sending off into the air, upon the slightest breath of wind, clouds of buoyant pollen! That the zephyr should so rarely intervene to fecundate the plants of one species with the anther-dust of others, seems almost to realize the converse of the miracle believed by the credulous herdsmen of the Lusitanian mares —

> Ore omnes versæ in Zephyrum, stant rupibus altis
> Exceptantque leves auras: et sæpe sine ullis
> Conjugiis, vento gravidæ, mirabile dictu.†

But, in the first place, it appears that there is a natural aversion in plants, at well as in animals, to irregular sexual unions; and in most of the successful experiments in the animal and vegetable world, some violence has been used in order to procure impregnation. The stigma imbibes, slowly and reluctantly, the

* See Barton on the Geography of Plants, p. 67.
† Georg. lib. iii. 273.

granules of the pollen of another species, even when it is abundantly covered with it; and if it happen that, during this period, ever so slight a quantity of the anther-dust of its own species alight upon it, this is instantly absorbed, and the effect of the foreign pollen destroyed. Besides, it does not often happen that the male and female organs of fructification, in different species, arrive at a state of maturity at precisely the same time. Even where such synchronism does prevail, so that a cross impregnation is effected, the chances are very numerous against the establishment of a hybrid race.

If we consider the vegetable kingdom generally, it must be recollected that even of the seeds which are well ripened, a great part are either eaten by insects, birds, and other animals, or decay for want of room and opportunity to germinate. Unhealthy plants are the first which are cut off by causes prejudicial to the species, being usually stifled by more vigorous individuals of their own kind. If, therefore, the relative fecundity or hardiness of hybrids be in the least degree inferior, they cannot maintain their footing for many generations, even if they were ever produced beyond one generation in a wild state. In the universal struggle for existence, the right of the strongest eventually prevails; and the strength and durability of a race depends mainly on its prolificness, in which hybrids are acknowledged to be deficient.

Centaurea hybrida, a plant which never bears seed, and is supposed to be produced by the frequent intermixture of two well-known species of Centaurea, grows wild upon a hill near Turin. *Ranunculus lacerus*, also sterile, has been produced accidentally at Grenoble,

and near Paris, by the union of two Ranunculi; but this occurred in gardens.*

Mr. Herbert's experiments.— Mr. Herbert, in one of his ingenious papers on mule plants, endeavours to account for their non-occurrence in a state of nature, from the circumstance that all the combinations that were likely to occur have already been made many centuries ago, and have formed the various species of botanists; but in our gardens, he says, whenever species, having a certain degree of affinity to each other, are transported from different countries, and brought for the first time into contact, they give rise to hybrid species.† But we have no data, as yet, to warrant the conclusion, that a single permanent hybrid race has ever been formed, even in gardens, by the intermarriage of two allied species brought from distant habitations. Until some fact of this kind is fairly established, and a new species, capable of perpetuating itself in a state of perfect independence of man, can be pointed out, it seems reasonable to call in question entirely this hypothetical source of new species. That varieties do sometimes spring up from cross breeds, in a natural way, can hardly be doubted; but they probably die out even more rapidly than races propagated by grafts or layers.

Opinion of De Candolle.—De Candolle, whose opinion on a philosophical question of this kind deserves the greatest attention, has observed, in his Essay on Botanical Geography, that the *varieties* of plants range themselves under two general heads: those produced by external circumstances, and those formed by hybridity. After adducing various argu-

* Hon. and Rev. W. Herbert, Hort. Trans. vol. iv. p. 41.

† Ibid.

ments to show that neither of these causes can explain the permanent diversity of plants indigenous in different regions, he says, in regard to the crossing of races, "I can perfectly comprehend, without altogether sharing the opinion, that, where many species of the same genera occur near together, hybrid species may be formed, and I am aware that the great number of species of certain genera which are found in particular regions may be explained in this manner; but I am unable to conceive how any one can regard the same explanation as applicable to species which live naturally at great distances. If the three larches, for example, now known in the world, lived in the same localities, I might then believe that one of them was the produce of the crossing of the two others; but I never could admit that the Siberian species has been produced by the crossing of those of Europe and America. I see, then, that there exist, in organized beings, permanent differences which cannot be referred to any one of the actual causes of variation, and these differences are what constitute *species*." *

Reality of species confirmed by the phenomena of hybrids. — The most decisive arguments, perhaps, amongst many others, against the probability of the derivation of permanent species from cross-breeds, are to be drawn from the fact alluded to by De Candolle, of species having a close affinity to each other occurring in distinct botanical provinces, or countries inhabited by groups of distinct species of indigenous plants: for in this case naturalists, who are not prepared to go the whole length of the transmutationists, are under the necessity of admitting that, in some

* Essai Elèmentaire, &c., 3me partie.

cases, species which approach very near to each other in their characters, were so created from their origin; an admission fatal to the idea of its being a general law of nature, that a few original types only should be formed, and that all intermediate races should spring from the intermixture of those stocks.

This notion, indeed, is wholly at variance with all that we know of hybrid generation; for the phenomena entitle us to affirm, that had the types been at first somewhat distant, *no cross-breeds would ever have been produced*, much less those prolific races which we now recognize as distinct species.

In regard, moreover, to the permanent propagation of hybrid races among animals, insuperable difficulties present themselves, when we endeavour to conceive the blending together of the different instincts and propensities of two species, so as to insure the preservation of the intermediate race. The common mule, when obtained by human art, may be protected by the power of man; but, in a wild state, it would not have precisely the same wants either as the horse or the ass: and if, in consequence of some difference of this kind, it strayed from the herd, it would soon be hunted down by beasts of prey, and destroyed.

If we take some genus of insects, such as the bee, we find that each of the numerous species has some difference in its habits, its mode of collecting honey, or constructing its dwelling, or providing for its young, and other particulars. In the case of the common hive-bee, the workers are described, by Kirby and Spence, as being endowed with no less than thirty distinct instincts.* So also we find that, amongst a most

* Intr. to Entom., vol. ii. p. 504. Ed. 1817.

numerous class of spiders, there are nearly as many different modes of spinning their webs as there are species. When we recollect how complicated are the relations of these instincts with co-existing species, both of the animal and vegetable kingdoms, it is scarcely possible to imagine that a bastard race could spring from the union of two of these species, and retain just so much of the qualities of each parent stock as to preserve its ground in spite of the dangers which surround it.

We might also ask, if a few generic types alone have been *created* among insects, and the intermediate species have proceeded from hybridity, where are those original types, combining, as they ought to do, the elements of all the instincts which have made their appearance in the numerous derivative races? So also in regard to animals of all classes, and of plants; if species in general are of hybrid origin, where are the stocks which combine in themselves the habits, properties, and organs, of which all the intervening species ought to afford us mere modifications?

Recapitulation of the arguments from hybrids.—I shall now conclude this subject by summing up, in a few words, the results to which I have been led by the consideration of the phenomena of hybrids. It appears, that the aversion of individuals of distinct species to the sexual union is common to animals and plants; and that it is only when the species approach near to each other in their organization and habits, that any offspring are produced from their connexion. Mules are of extremely rare occurrence in a state of nature, and no examples are yet known of their having procreated in a wild state. But it has been proved, that hybrids are not universally sterile, provided the parent

stocks have a near affinity to each other, although the continuation of the mixed race, for several generations, appears hitherto to have been obtained only by crossing the hybrids with individuals of pure species; an experiment which by no means bears out the hypothesis that a true hybrid race could ever be permanently established.

Hence we may infer, that aversion to sexual intercourse is, in general, a good test of the distinctness of original stocks, or of *species;* and the procreation of hybrids is a proof of the very near affinity of species. Perhaps, hereafter, the number of generations for which hybrids may be continued, before the race dies out (for it seems usually to degenerate rapidly), may afford the zoologist and botanist an experimental test of the difference in the degree of affinity of allied species.

I may also remark, that if it could have been shown that a single permanent species had ever been produced by hybridity (of which there is no satisfactory proof), it might certainly have lent some countenance to the notions of the ancients respecting the gradual deterioration of created things, but none whatever to Lamarck's theory of their progressive perfectibility; for observations have hitherto shown that there is a tendency in mule animals and plants to degenerate in organization.

It was before remarked, that the theory of progressive development arose from an attempt to ingraft the doctrines of the transmutationists upon one of the most popular generalizations in geology. But modern geological researches have almost destroyed every appearance of that gradation in the successive groups of animate beings, which was supposed to indicate the

slow progress of the organic world from the more simple to the more compound structure. In the more modern formations, we find clear indications that the highest orders of the terrestrial mammalia were fully represented during several successive epochs; but in the monuments which we have hitherto examined of more remote eras, in which there are as yet discovered few fluviatile, and lacustrine formations, and, therefore, scarcely any means of obtaining an insight into the zoology of the continents then existing, we have only as yet found in one locality two or three examples of mammiferous quadrupeds.* The recent origin of man, and the absence of all signs of any rational being holding an analogous relation to former states of the animate world, affords one, and the only reasonable argument, in support of the hypothesis of a progressive scheme; but none whatever in favour of the fancied evolution of one species out of another.

Theory of the gradation in intellect as shown by the facial angle.—When the celebrated anatomist, Camper, first attempted to estimate the degrees of sagacity of different animals, and of the races of man, by the measurement of the facial angle, some speculators were bold enough to affirm, that certain simiæ differed as little from the more savage races of men, as those do from the human race in general; and that a scale might be traced from "apes with foreheads villanous low" to the African variety of the human species, and from that to the European. The facial angle was measured by drawing a line from the prominent centre of the forehead to the most advanced part of the lower jaw-bone, and observing the angle which it made with

* See account of an opossum and another marsupial genus found at Stonesfield, book i. chap. ix.

the horizontal line; and it was affirmed, that there was a regular series of such angles from birds to the mammalia.

The gradation from the dog to the monkey was said to be perfect, and from that again to man. One of the ape tribe has a facial angle of 42°; and another, which approximated nearest to man in figure, an angle of 50°. To this succeeds (longo sed proximus intervallo) the head of the African negro, which, as well as that of the Kalmuc, forms an angle of 70°; while that of the European contains 80°. The Roman painters preferred the angle of 95°; and the character of beauty and sublimity, so striking in some works of Grecian sculpture, as in the head of the Apollo, and in the Medusa of Sisocles, is given by an angle which amounts to 100°.*

A great number of valuable facts and curious analogies in comparative anatomy were brought to light during the investigations which were made by Camper, John Hunter, and others, to illustrate this scale of organization; and their facts and generalizations must not be confounded with the fanciful systems which White and others deduced from them.†

That there is some connexion between an elevated and capacious forehead, in certain races of men, and a large development of the intellectual faculties, seems highly probable; and that a low facial angle is frequently accompanied with inferiority of mental powers, is certain; but the attempt to trace a graduated scale of intelligence through the different species of animals accompanying the modifications of the form of the skull, is a mere visionary speculation. It has been

* Prichard's Phys. Hist. of Mankind, vol. i. p. 159.

† Ch. White on the Regular Gradation in Man, &c., 1799.

found necessary to exaggerate the sagacity of the ape tribe at the expense of the dog; and strange contradictions have arisen in the conclusions deduced from the structure of the elephant; some anatomists being disposed to deny that quadruped the intelligence which he really possesses, because they found that the volume of his brain was small in comparison to that of the other mammalia; while others were inclined to magnify extravagantly the superiority of his intellect, because the vertical height of his skull is so great when compared to its horizontal length.

Different races of men are all of one species.—It would be irrelevant to our subject if we were to enter into a further discussion on these topics; because, even if a graduated scale of organization and intelligence could have been established, it would prove nothing in favour of a tendency, in each species, to attain a higher state of perfection. I may refer the reader to the writings of Blumenbach, Prichard, Lawrence, and others, for convincing proofs that the varieties of form, colour, and organization of different races of men, are perfectly consistent with the generally received opinion, that all the individuals of the species have originated from a single pair; and, while they exhibit in man as many diversities of a physiological nature as appear in any other species, they confirm also the opinion of the slight deviation from a common standard of which species are capable.

The power of existing and multiplying in every latitude, and in every variety of situation and climate, which has enabled the great human family to extend itself over the habitable globe, is partly, says Lawrence, the result of physical constitution, and partly of the mental prerogative of man. If he did not possess the

most enduring and flexible corporeal frame, his arts would not enable him to be the inhabitant of all climates, and to brave the extremes of heat and cold, and the other destructive influences of local situation.* Yet, notwithstanding this flexibility of bodily frame, we find no signs of indefinite departure from a common standard, and the intermarriages of individuals of the most remote varieties are not less fruitful than between those of the same tribe.

Tiedemann on the brain of the fœtus in vertebrated animals.—There is yet another department of anatomical discovery to which I must allude, because it has appeared to some persons to afford a distant analogy, at least, to that progressive development by which some of the inferior species may have been gradually perfected into those of more complex organization. Tiedemann found, and his discoveries have been most fully confirmed and elucidated by M. Serres, that the brain of the fœtus, in the highest class of vertebrated animals, assumes, in succession, forms analogous to those which belong to fishes, reptiles, and birds, before it acquires the additions and modifications which are peculiar to the mammiferous tribe. So that, in the passage from the embryo to the perfect mammifer, there is a typical representation, as it were, of all those transformations which the primitive species are supposed to have undergone, during a long series of generations, between the present period and the remotest geological era.

If you examine the brain of the mammalia, says M. Serres, at an early stage of uterine life, you per-

* Lawrence, Lectures on Phys. Zool. and Nat. Hist. of Man, p. 192. Ed. 1823.

ceive the cerebral hemispheres consolidated, as in fish, in two vesicles, isolated one from the other; at a later period, you see them affect the configuration of the cerebral hemispheres of reptiles; still later again, they present you with the forms of those of birds; finally, they acquire, at the era of birth, and sometimes later, the permanent forms which the adult mammalia present.

The cerebral hemispheres, then, arrive at the state which we observe in the higher animals only by a series of successive metamorphoses. If we reduce the whole of these evolutions to four periods, we shall see, that in the first are born the cerebral lobes of fishes; and this takes place homogeneously in all classes. The second period will give us the organization of reptiles; the third, the brain of birds; and the fourth, the complex hemispheres of mammalia.

If we could develop the different parts of the brain of the inferior classes, we should make, in succession, a reptile out of a fish, a bird out of a reptile, and a mammiferous quadruped out of a bird. If, on the contrary, we could starve this organ in the mammalia, we might reduce it successively to the condition of the brain of the three inferior classes.

Nature often presents us with this last phenomenon in monsters, but never exhibits the first. Among the various deformities which organized beings may experience, they never pass the limits of their own classes to put on the forms of the class above them. Never does a fish elevate itself so as to assume the form of the brain of a reptile; nor does the latter ever attain that of birds; nor the bird that of the mammifer. It may happen that a monster may have two heads; but

the conformation of the brain always remains circumscribed narrowly within the limits of its class.*

Bearing of these discoveries on the theory of progressive development.— It will be observed, that these curious phenomena disclose, in a highly interesting manner, the unity of plan that runs through the organization of the whole series of vertebrated animals; but they lend no support whatever to the notion of a gradual transmutation of one species into another; least of all of the passage, in the course of many generations, from an animal of a more simple to one of a more complex structure. On the contrary, were it not for the sterility imposed on monsters, as well as on hybrids in general, the argument to be derived from Tiedemann's discovery, like that deducible from experiments respecting hybridity, would be in favour of the successive *degeneracy*, rather than the perfectibility, in the course of ages, of certain classes of organic beings.

Recapitulation.— For the reasons, therefore, detailed in this and the two preceding chapters, we may draw the following inferences in regard to the reality of *species* in nature:—

1st. That there is a capacity in all species to accommodate themselves, to a certain extent, to a change of external circumstances, this extent varying greatly, according to the species.

2dly. When the change of situation which they can endure is great, it is usually attended by some modifications of the form, colour, size, structure, or other particulars; but the mutations thus superinduced are

* E. R. A. Serres, Anatomie Comparée du Cerveau, illustrated by numerous plates, tome i., 1824.

governed by constant laws, and the capability of so varying forms part of the permanent specific character.

3dly. Some acquired peculiarities of form, structure, and instinct, are transmissible to the offspring; but these consist of such qualities and attributes only as are intimately related to the natural wants and propensities of the species.

4thly. The entire variation from the original type, which any given kind of change can produce, may usually be effected in a brief period of time, after which no farther deviation can be obtained by continuing to alter the circumstances, though ever so gradually; indefinite divergence, either in the way of improvement or deterioration, being prevented, and the least possible excess beyond the defined limits being fatal to the existence of the individual.

5thly. The intermixture of distinct species is guarded against by the aversion of the individuals composing them to sexual union, or by the sterility of the mule offspring. It does not appear that true hybrid races have ever been perpetuated for several generations, even by the assistance of man; for the cases usually cited relate to the crossing of mules with individuals of pure species, and not to the intermixture of hybrid with hybrid.

6thly. From the above considerations, it appears that species have a real existence in nature; and that each was endowed, at the time of its creation, with the attributes and organization by which it is now distinguished.

CHAPTER V.

LAWS WHICH REGULATE THE GEOGRAPHICAL DISTRIBUTION OF SPECIES.

Analogy of climate not attended with identity of species — Botanical geography — Stations — Habitations — Distinct provinces of indigenous plants — Vegetation of islands — Marine vegetation — In what manner plants become diffused — Effects of wind, rivers, marine currents — Agency of Animals — Many seeds pass through the stomachs of animals and birds undigested — Agency of man in the dispersion of plants, both voluntary and involuntary — Its analogy to that of the inferior animals.

Next to determining the question whether species have a real existence, the consideration of the laws which regulate their geographical distribution is a subject of primary importance to the geologist. It is only by studying these laws with attention, by observing the positions which groups of species occupy at present, and inquiring how these may be varied in the course of time by migrations, by changes in physical geography, and other causes, that we can hope to learn whether the duration of species be limited, or in what manner the state of the animate world is affected by the endless vicissitudes of the inanimate.

Different regions inhabited by distinct species.—That different regions of the globe are inhabited by entirely distinct animals and plants, is a fact which has been

familiar to all naturalists since Buffon first pointed out the want of *specific* identity between the land quadrupeds of America and those of the Old World. The same phenomenon has, in later times, been forced in a striking manner upon our attention, by the examination of New Holland, where the indigenous species of animals and plants were found to be, almost without exception, distinct from those known in other parts of the world.

But the extent of this parcelling out of the globe amongst different *nations*, as they have been termed, of plants and animals—the universality of a phenomenon so extraordinary and unexpected, may be considered as one of the most interesting facts clearly established by the advance of modern science.

Scarcely fourteen hundred species of plants appear to have been known and described by the Greeks, Romans, and Arabians. At present, more than three thousand species are enumerated, as natives of our own island.* In other parts of the world there have been collected, perhaps, upwards of seventy thousand species. It was not to be supposed, therefore, that the ancients should have acquired any correct notions respecting what may be called the geography of plants, although the influence of climate on the character of the vegetation could hardly have escaped their observation.

Antecedently to investigation, there was no reason for presuming that the vegetable productions, growing wild in the eastern hemisphere, should be unlike those of the western, in the same latitude; nor that the plants of the Cape of Good Hope should be unlike

* Barton's Lectures on the Geography of Plants, p. 2., 1827.

those of the South of Europe; situations where the climate is little dissimilar. The contrary supposition would have seemed more probable, and we might have anticipated an almost perfect identity in the animals and plants which inhabit corresponding parallels of latitude. The discovery, therefore, that each separate region of the globe, both of the land and water, is occupied by distinct groups of species, and that most of the exceptions to this general rule may be referred to disseminating causes now in operation, is eminently calculated to excite curiosity, and to stimulate us to seek some hypothesis respecting the first introduction of species which may be reconcileable with such phenomena.

Botanical geography. — A comparison of the *plants* of different regions of the globe affords results more to be depended upon in the present state of our knowledge than those relating to the animal kingdom, because the science of botany is more advanced, and probably comprehends a great proportion of the total number of the vegetable productions of the whole earth. Humboldt, in several eloquent passages of his Personal Narrative, was among the first to promulgate philosophical views on this subject. Every hemisphere, says this traveller, produces plants of different species; and it is not by the diversity of climates that we can attempt to explain why equinoctial Africa has no laurineæ, and the New World no heaths; why the calceolariæ are found only in the southern hemisphere; why the birds of the continent of India glow with colours less splendid than the birds of the hot parts of America; finally, why the tiger is peculiar to Asia, and the ornithorhynchus to New Holland.*

* Pers. Nar., vol. v. p. 180.

"We can conceive," he adds, "that a small number of the families of plants, for instance, the musaceæ and the palms, cannot belong to very cold regions, on account of their internal structure and the importance of certain organs; but we cannot explain why no one of the family of melastomas vegetates north of the parallel of thirty degrees; or why no rose-tree belongs to the southern hemisphere. Analogy of climates is often found in the two continents without identity of productions." *

The luminous essay of De Candolle on "Botanical Geography" presents us with the fruits of his own researches, and those of Humboldt, Brown, and other eminent botanists, so arranged, that the principal phenomena of the distribution of plants are exhibited in connexion with the causes to which they are chiefly referable.† "It might not, perhaps, be difficult," observes this writer, "to find two points, in the United States and in Europe, or in equinoctial America and Africa, which present all the same circumstances: as, for example, the same temperature, the same height above the sea, a similar soil, an equal dose of humidity; yet nearly all, *perhaps all*, the plants in these two similar localities shall be distinct. A certain degree of analogy, indeed, of aspect, and even of structure, might very possibly be discoverable between the plants of the two localities in question; but the *species* would in general be different. Circumstances, therefore, different from those which now determine the *stations*, have had an influence on the *habitations* of plants."

* Pers. Nar., vol. v. p. 180.

† Essai E'lémentaire de Géographie Botanique. Extrait du 18me vol. du Dict. des Sci. Nat.

Stations and habitations of plants. — As I shall frequently have occasion to speak of the *stations* and *habitations* of plants in the technical sense in which the terms are used in the above passage, I may remind the geologist that station indicates the peculiar nature of the locality where each species is accustomed to grow, and has reference to climate, soil, humidity, light, elevation above the sea, and other analogous circumstances; whereas, by habitation is meant a general indication of the country where a plant grows wild. Thus the *station* of a plant may be a salt-marsh, in a temperate climate, a hill-side, the bed of the sea, or a stagnant pool. Its *habitation* may be Europe, North America, or New Holland between the tropics. The study of stations has been styled the topography, that of habitations the geography, of botany. The terms thus defined, express each a distinct class of ideas, which have been often confounded together, and which are equally applicable in zoology.

In further illustration of the principle above alluded to, that difference of longitude, independently of any influence of temperature, is accompanied by a great, and sometimes a complete, diversity in the species of plants, De Candolle observes, that, out of 2891 species of phænogamous plants described by Pursh, in the United States, there are only 385 which are found in northern or temperate Europe. MM. Humboldt and Bonpland, in all their travels through equinoctial America, found only twenty-four species (these being all cyperaceæ and gramineæ) common to America and any part of the Old World. On comparing New Holland with Europe, Mr. Brown ascertained that, out of 4100 species, discovered in Australia, there were only

166 common to Europe, and of this small number there were some few which may have been transported thither by man.

But it is still more remarkable, that in the more widely separated parts of the ancient continent, notwithstanding the existence of an uninterrupted land-communication, the diversity in the specific character of the respective vegetations is almost as striking. Thus there is found one assemblage of species in China, another in the countries bordering the Black Sea and the Caspian, a third in those surrounding the Mediterranean, a fourth in the great platforms of Siberia and Tartary, and so forth.

The distinctness of the groups of indigenous plants, in the same parallel of latitude, is greatest where continents are disjoined by a wide expanse of ocean. In the northern hemisphere, near the pole, where the extremities of Europe, Asia, and America unite or approach near to one another, a considerable number of the same species of plants are found, common to the three continents. But it has been remarked, that these plants, which are thus so widely diffused in the Arctic regions, are also found in the chain of the Aleutian islands, which stretch almost across from America to Asia, and which may probably have served as the channel of communication for the partial blending of the Floras of the adjoining regions. It has, indeed, been found to be a general rule, that plants found at two points very remote from each other occur also in places intermediate.

Vegetation of islands.—In islands very distant from continents the total number of plants is comparatively small; but a large proportion of the species are such

as occur nowhere else. In so far as the Flora of such islands is not peculiar to them, it contains, in general, species common to the nearest main lands.*

The islands of the great southern ocean exemplify these rules; the easternmost containing more American, and the western more Indian, plants.† Madeira and Teneriffe contain many species, and even entire genera, peculiar to them; but they have also plants in common with Portugal, Spain, the Azores, and the north-west coast of Africa.‡

In the Canaries, out of 533 species of phænogamous plants, it is said that 310 are peculiar to these islands, and the rest identical with those of the African continent; but in the Flora of St. Helena, which is so far distant even from the western shores of Africa, there have been found, out of sixty-one native species, only *two or three* which are to be found in any other part of the globe.

Number of botanical provinces.—De Candolle has enumerated twenty great botanical provinces inhabited by indigenous or aboriginal plants; and although many of these contain a variety of species which are common to several others, and sometimes to places very remote, yet the lines of demarcation are, upon the whole, astonishingly well defined.§ Nor is it likely that the bearing of the evidence on which these general views are founded will ever be materially affected, since they

* Prichard, vol. i. p. 36. Brown, Appendix to Flinders.

† Forster, Observations, &c.

‡ Humboldt, Pers. Nar., vol. i. p. 270. of the translation. Prichard, Phys. Hist. of Mankind, vol. i. p. 37.

§ See a farther subdivision, by which twenty-seven provinces are made, by M. Alph. De Candolle, son of De Candolle. Monogr. des Campanulées. Paris, 1830.

are already confirmed by the examination of seventy or eighty thousand species of plants.

The entire change of opinion which the contemplation of these phenomena has brought about is worthy of remark. The first travellers were persuaded that they should find, in distant regions, the plants of their own country, and they took a pleasure in giving them the same names. It was some time before this illusion was dissipated; but so fully sensible did botanists at last become of the extreme smallness of the number of phænogamous plants common to different continents, that the ancient Floras fell into disrepute. All grew diffident of the pretended identifications; and we now find that every naturalist is inclined to examine each supposed exception with scrupulous severity.* If they admit the fact, they begin to speculate on the mode whereby the seeds may have been transported from one country into the other, or inquire on which of two continents the plant was indigenous, assuming that a species, like an individual, cannot have two birth-places.

Marine vegetation.—The marine vegetation is less known; but we learn from Lamouroux, that it is divisible into different systems, apparently as distinct as those on the land, notwithstanding that the uniformity of temperature is so much greater in the ocean. For on that ground we might have expected the phenomenon of partial distribution to have been far less striking, since climate is, in general, so influential a cause in checking the dispersion of species from one zone to another.

The number of hydrophytes, as they are termed, is

* De Candolle, Essai Elémen. de Géog. Botan., p. 45.

very considerable, and their stations are found to be infinitely more varied than could have been anticipated; for while some plants are covered and uncovered daily by the tide, others live in abysses of the ocean, at the extraordinary depth of one thousand feet; and although in such situations there must reign darkness more profound than night, at least to our organs, many of these vegetables are highly coloured. From the analogy of terrestrial plants we might have inferred, that the colouring of the algæ was derived from the influence of the solar rays; yet we are compelled to doubt when we reflect how feeble must be the rays which penetrate to these great depths.

The subaqueous vegetation of the Mediterranean is, upon the whole, distinct from that of the Atlantic on the west, and that part of the Arabian gulf which is immediately contiguous on the south. Other botanical provinces are found in the West Indian seas, including the gulf of Mexico; in the ocean which washes the shores of South America; in the Indian Ocean and its gulfs; in the seas of Australia; and in the Atlantic basin, from the 40th degree of north latitude to the pole. There are very few species common to the coast of Europe and the United States of North America, and none common to the Straits of Magellan and the shores of Van Diemen's Land.

It must not be overlooked, that the distinctness alluded to between the vegetation of these several countries relates strictly to *species*, and not to forms. In regard to the numerical preponderance of certain forms, and many peculiarities of internal structure, there is a marked agreement in the vegetable productions of districts placed in corresponding latitudes, and under similar physical circumstances, however remote

their position. Thus there are innumerable points of analogy between the vegetation of the Brazils, equinoctial Africa, and India; and there are also points of difference wherein the plants of these regions are distinguishable from all extra-tropical groups. But there are very few species common to the three continents. The same may be said, if we compare the plants of the United States with that of the middle of Europe: the species are distinct, but the forms are in a great degree analogous.

Let us now consider what means of diffusion, independently of the agency of man, are possessed by plants, whereby, in the course of ages, they may be enabled to stray from one of the botanical provinces above mentioned to another, and to establish new colonies at a great distance from their birth-place.

Manner in which plants become diffused.—Winds.— The principal of the inanimate agents provided by nature for scattering the seeds of plants over the globe, are the movements of the atmosphere and of the ocean, and the constant flow of water from the mountains to the sea. To begin with the winds: a great number of seeds are furnished with downy and feathery appendages, enabling them, when ripe, to float in the air, and to be wafted easily to great distances by the most gentle breeze. Other plants are fitted for dispersion by means of an attached wing, as in the case of the fir-tree, so that they are caught up by the wind as they fall from the cone, and are carried to a distance. Amongst the comparatively small number of plants known to Linnæus, no less than 138 genera are enumerated as having winged seeds.

As winds often prevail for days, weeks, or even months together, in the same direction, these means

of transportation may sometimes be without limits; and even the heavier grains may be borne through considerable spaces, in a very short time, during ordinary tempests; for strong gales, which can sweep along grains of sand, often move at the rate of about forty miles an hour, and if the storm be very violent, at the rate of fifty-six miles.* The hurricanes of tropical regions, which root up trees and throw down buildings, sweep along at the rate of ninety miles an hour; so that, for however short a time they prevail, they may carry even the heavier fruits and seeds over friths and seas of considerable width, and, doubtless, are often the means of introducing into islands the vegetation of adjoining continents. Whirlwinds are also instrumental in bearing along heavy vegetable substances to considerable distances. Slight ones may frequently be observed in our fields, in summer, carrying up haycocks into the air, and then letting fall small tufts of hay far and wide over the country; but they are sometimes so powerful as to dry up lakes and ponds, and to break off the boughs of trees, and carry them up in a whirling column of air.

Franklin tells us, in one of his letters, that he saw, in Maryland, a whirlwind which began by taking up the dust which lay in the road, in the form of a sugar-loaf with the pointed end downwards, and soon after grew to the height of forty or fifty feet, being twenty or thirty in diameter. It advanced in a direction contrary to the wind; and although the rotatory motion of the column was surprisingly rapid, its onward progress was sufficiently slow to allow a man to keep pace with it on foot. Franklin followed it on horseback, accom-

* Annuaire du Bureau des Longitudes.

panied by his son, for three quarters of a mile, and saw it enter a wood, where it twisted and turned round large trees with surprising force. These were carried up in a spiral line, and were seen flying in the air, together with boughs and innumerable leaves, which, from their height, appeared reduced to the apparent size of flies. As this cause operates at different intervals of time throughout a great portion of the earth's surface, it may be the means of bearing not only plants but insects, land-testacea and their eggs, with many other species of animals, to points which they could never otherwise have reached, and from which they may then begin to propagate themselves again as from a new centre.

Distribution of cryptogamous plants.—It has been found that a great numerical proportion of the exceptions to the limitation of species to certian quarters of the globe occur in the various tribes of cryptogamic plants. Linnæus observed that, as the germs of plants of this class, such as mosses, fungi, and lichens, consist of an impalpable powder, the particles of which are scarcely visible to the naked eye, there is no difficulty to account for their being dispersed throughout the atmosphere, and carried to every point of the globe, where there is a station fitted for them. Lichens in particular ascend to great elevations, sometimes growing two thousand feet above the line of perpetual snow, at the utmost limits of vegetation, and where the mean temperature is nearly at the freezing point. This elevated position must contribute greatly to facilitate the dispersion of those buoyant particles of which their fructification consists.*

* Linn., Tour in Lapland, vol. ii, p. 282.

Some have inferred, from the springing up of mushrooms whenever particular soils and decomposed organic matter are mixed together, that the production of fungi is accidental, and not analogous to that of perfect plants. But Fries, whose authority on these questions is entitled to the highest respect, has shown the fallacy of this argument in favour of the old doctrine of equivocal generation. "The sporules of fungi," says this naturalist, "are so infinite, that in a single individual of *Reticularia maxima,* I have counted above ten millions, and so subtile as to be scarcely visible, often resembling thin smoke; so light that they may be raised perhaps by evaporation into the atmosphere, and dispersed in so many ways by the attraction of the sun, by insects, wind, elasticity, adhesion, &c., that it is difficult to conceive a place from which they may be excluded."*

Agency of rivers and currents.— In considering, in the next place, the instrumentality of the aqueous agents of dispersion, I cannot do better than cite the words of one of our ablest botanical writers. "The mountain stream or torrent," observes Keith, "washes down to the valley the seeds which may accidentally fall into it, or which it may happen to sweep from its banks when it suddenly overflows them. The broad and majestic river, winding along the extensive plain, and traversing the continents of the world, conveys to the distance of many hundreds of miles the seeds that may have vegetated at its source. Thus the southern shores of the Baltic are visited by seeds which grew in the interior of Germany; and the western shores of the Atlantic by seeds that have been generated in the

* Fries, cited by Lindley, Introd. to Nat. Syst. of Botany.

interior of America."* Fruits, moreover, indigenous to America and the West Indies, such as that of the *Mimosa scandens*, the cashew-nut, and others, have been known to be drifted across the Atlantic by the Gulf stream, on the western coasts of Europe, in such a state that they might have vegetated had the climate and soil been favourable. Among these the *Guilandina Bonduc*, a leguminous plant, is particularly mentioned, as having been raised from a seed found on the west coast of Ireland.†

Sir Hans Sloane states, that several kinds of beans cast ashore on the Orkney Isles, and Ireland, but none of which appear to have naturalized themselves, are derived from trees which grow in the West Indies, and many of them in Jamaica. He conjectures that they may have been conveyed by rivers into the sea, and then by the Gulf stream to greater distances, in the same manner as the sea-weed called *Lenticula marina*, or Sargasso, which grows on the rocks about Jamaica, is known to be "carried by the winds and current towards the coast of Florida, and thence into the North American ocean, where it lies very thick on the surface of the sea."‡

The absence of liquid matter in the composition of seeds renders them comparatively insensible to heat and cold, so that they may be carried without detriment through climates where the plants themselves would instantly perish. Such is their power of resisting the effects of heat, that Spallanzani mentions some seeds that germinated after having been boiled in

* System of Physiological Botany, vol. ii. p. 405.

† Brown, Append. to Tuckey, No. V. p. 481.

‡ Phil. Trans. 1696.

water.* Sir John Herschel informs me that he has sown at the Cape of Good Hope the seeds of the *Acacia lophanta* after they had remained for twelve hours in water of 140° Fahrenheit, and they germinated far more rapidly than unboiled seeds. He also states that an eminent botanist, Baron Ludwig, could not get the seeds of a species of cedar to grow at the Cape till they were thoroughly boiled.

When, therefore, a strong gale, after blowing violently off the land for a time, dies away, and the seeds alight upon the surface of the waters, or wherever the ocean, by eating away the sea-cliffs, throws down into its waves plants which would never otherwise reach the shores, the tides and currents become active instruments in assisting the dissemination of almost all classes of the vegetable kingdom.

In a collection of six hundred plants from the neighbourhood of the river Zaire, in Africa, Mr. Brown found that thirteen species were also met with on the opposite shores of Guiana and Brazil. He remarked that most of these plants were found only on the lower parts of the river Zaire, and were chiefly such as produced seeds capable of retaining their vitality a long time in the currents of the ocean.

The migration of plants aided by islands. — Islands, moreover, and even the smallest rocks, play an important part in aiding such migrations; for when seeds alight upon them from the atmosphere, or are thrown up by the surf, they often vegetate, and supply the winds and waves with a repetition of new and uninjured crops of fruit and seeds. These may afterwards pursue their course through the atmosphere, or along the surface of the sea, in the same direction.

* System of Physiological Botany, vol. ii. p. 403.

The number of plants found at any given time on an islet affords us no test whatever of the extent to which it may have co-operated towards this end, since a variety of species may first thrive there and then perish, and be followed by other chance-comers like themselves.

Currents and winds in the arctic regions drift along icebergs covered with an alluvial soil, on which herbs and pine-saplings are seen growing, which may often continue to vegetate on some distant shore where the ice-island is stranded.

Dispersion of marine plants.—With respect to marine vegetation, the seeds, being in their native element, may remain immersed in water without injury for indefinite periods, so that there is no difficulty in conceiving the diffusion of species wherever uncongenial climates, contrary currents, and other causes do not interfere. All are familiar with the sight of the floating sea-weed,

> "Flung from the rock on ocean's foam to sail,
> Where'er the surge may sweep, the tempest's breath prevail."

Remarkable accumulations of that species of sea-weed generally known as gulf-weed, or sargasso, occur on each side of the equator in the Atlantic, Pacific, and Indian Oceans. Columbus and other navigators, who first encountered these banks of algæ in the Northern Atlantic, compared them to vast inundated meadows, and state that they retarded the progress of their vessels. The most extensive bank is a little west of the meridian of Fayal, one of the Azores, between latitudes 35° and 36°: violent north winds sometimes prevail in this space, and drive the sea-

weed to low latitudes, as far as the 24th or even the 20th degree.*

The hollow pod-like receptacles in which the seeds of many algæ are lodged, and the filaments attached to the seed-vessels of others, seem intended to give buoyancy; and I may observe that these hydrophytes are in general *proliferous*, so that the smallest fragment of a branch can be developed into a perfect plant. The seeds, moreover, of the greater number of species are enveloped with a mucous matter like that which surrounds the eggs of some fish, and which not only protects them from injury, but serves to attach them to floating bodies or to rocks.

Agency of animals in the distribution of plants.— But we have as yet considered part only of the fertile resources of nature for conveying seeds to a distance from their place of growth. The various tribes of animals are busily engaged in furthering an object whence they derive such important advantages. Sometimes an express provision is found in the structure of seeds to enable them to adhere firmly by prickles, hooks, and hairs, to the coats of animals, or feathers of the winged tribe, to which they remain attached for weeks, or even months, and are borne along into every region whither birds or quadrupeds may migrate. Linnæus enumerates fifty genera of plants, and the number now known to botanists is much greater, which are armed with hooks, by which, when ripe, they adhere to the coats of animals. Most of these vegetables, he remarks, require a soil enriched with dung. Few have failed to mark the locks of wool hanging on the thorn-bushes, wherever the sheep pass, and it is

* Greville, Introduction to Algæ Britannicæ, p. 12.

probable that the wolf or lion never give chase to herbivorous animals without being unconsciously subservient to this part of the vegetable economy.

A deer has strayed from the herd when browsing on some rich pasture, when he is suddenly alarmed by the approach of his foe. He instantly takes to flight, dashing through many a thicket, and swimming across many a river and lake. The seeds of the herbs and shrubs which have adhered to his smoking flanks, are washed off again by the waters. The thorny spray is torn off, and fixes itself in his hairy coat, until brushed off again in other thickets and copses. Even on the spot where the victim is devoured many of the seeds which he had swallowed immediately before the chase may be left on the ground uninjured, and ready to spring up in a new soil.

The passage, indeed, of undigested seeds through the stomachs of animals is one of the most efficient causes of the dissemination of plants, and is of all others, perhaps, the most likely to be overlooked. Few are ignorant that a portion of the oats eaten by a horse preserve their germinating faculty in the dung. The fact of their being still nutritious is not lost on the sagacious rook. To many, says Linnæus, it seems extraordinary, and something of a prodigy, that when a field is well tilled and sown with the best of wheat, it frequently produces darnel or the wild oat, especially if it be manured with new dung: they do not consider that the fertility of the smaller seeds is not destroyed in the stomachs of animals.*

Agency of birds.— Some birds of the order Passeres devour the seeds of plants in great quantities, which

* Linnæus, Amœn. Acad., vol. ii. p. 409.

they eject again in very distant places, without destroying its faculty of vegetation; thus a flight of larks will fill the cleanest field with a great quantity of various kinds of plants, as the melilot trefoil (*Medicago lupulina*), and others whose seeds are so heavy that the wind is not able to scatter them to any distance.* In like manner, the blackbird and misselthrush, when they devour berries in too great quantities, are known to consign them to the earth undigested in their excrement.†

Pulpy fruits serve quadrupeds and birds as food, while their seeds, often hard and indigestible, pass uninjured through the intestines, and are deposited far from their original place of growth in a condition peculiarly fit for vegetation.‡ So well are the farmers, in some parts of England, aware of this fact, that when they desire to raise a quickset hedge in the shortest possible time, they feed turkeys with the haws of the common white-thorn (*Cratægus Oxyacantha*), and then sow the stones which are ejected in their excrement, whereby they gain an entire year in the growth of the plant.§ Birds when they pluck cherries, sloes, and haws, fly away with them to some convenient place; and when they have devoured the fruit, drop the stone into the ground. Captain Cook, in his account of the volcanic island of Tanna, one of the New Hebrides, which he visited in his second voyage, makes the following interesting observation:—"Mr. Forster, in his botanical excursion this day, shot a pigeon, in the craw

* Amœn. Acad., vol. iv. Essay 75. § 8.

† Ibid., vol. vi. § 22.

‡ Smith's Introd. to Phys. and Syst. Botany, p. 304. 1807.

§ This information was communicated to me by Professor Henslow, of Cambridge.

of which was a wild nutmeg. He took some pains to find the tree on this island, but his endeavours were without success."* It is easy, therefore, to perceive, that birds in their migrations to great distances, and even across seas, may transport seeds to new isles and continents.

The sudden deaths to which great numbers of frugivorous birds are annually exposed must not be omitted as auxiliary to the transportation of seeds to new habitations. When the sea retires from the shore, and leaves fruits and seeds on the beach, or in the mud of estuaries, it might, by the returning tide, wash them away again, or destroy them by long immersion; but when they are gathered by land birds which frequent the sea-side, or by waders and water-fowl, they are often borne inland; and if the bird to whose crop they have been consigned is killed, they may be left to grow up far from the sea. Let such an accident happen but once in a century, or a thousand years, it will be sufficient to spread many of the plants from one continent to another; for in estimating the activity of these causes, we must not consider whether they act slowly in relation to the period of our observation, but in reference to the duration of species in general.

Let us trace the operation of this cause in connexion with others. A tempestuous wind bears the seeds of a plant many miles through the air, and then delivers them to the ocean; the oceanic current drifts them to a distant continent; by the fall of the tide they become the food of numerous birds, and one of these is seized by a hawk or eagle, which, soaring across hill and dale to a place of retreat, leaves, after devouring its prey,

* Book iii. ch. iv.

the unpalatable seeds to spring up and flourish in a new soil.

The machinery before adverted to is so capable of disseminating seeds over almost unbounded spaces, that were we more intimately acquainted with the economy of nature, we might probably explain all the instances which occur of the aberration of plants to great distances from their native countries. The real difficulty which must present itself to every one who contemplates the present geographical distribution of species, is the small number of exceptions to the rule of the non-intermixture of different groups of plants. Why have they not, supposing them to have been ever so distinct originally, become more blended and confounded together in the lapse of ages?

Agency of man in the dispersion of plants.—But in addition to all the agents already enumerated as instrumental in diffusing plants over the globe, we have still to consider man—one of the most important of all. He transports with him, into every region, the vegetables which he cultivates for his wants; and is the involuntary means of spreading a still greater number which are useless to him, or even noxious. "When the introduction of cultivated plants," says De Candolle, "is of recent date, there is no difficulty in tracing their origin; but when it is of high antiquity, we are often ignorant of the true country of the plants on which we feed. No one contests the American origin of the maize or the potato; nor the origin, in the Old World, of the coffee-tree, and of wheat. But there are certain objects of culture, of very ancient date, between the tropics, such, for example, as the banana, of which the origin cannot be verified. Armies, in modern times, have been known to carry, in all

directions, grain and cultivated vegetables from one extremity of Europe to the other; and thus have shown us how, in more ancient times, the conquests of Alexander, the distant expeditions of the Romans, and afterwards the crusades, may have transported many plants from one part of the world to the other." *

But, besides the plants used in agriculture, the number which have been naturalized by accident, or which man has spread unintentionally, is considerable. One of our old authors, Josselyn, gives a catalogue of such plants as had, in his time, sprung up in the colony since the English planted and kept cattle in New England. They were two-and-twenty in number. The common nettle was the first which the settlers noticed; and the plantain was called by the Indians "Englishman's foot," as if it sprung from their footsteps.†

"We have introduced every where," observes De Candolle, "some weeds which grow among our various kinds of wheat, and which have been received, perhaps, originally from Asia along with them. Thus, together with the Barbary wheat, the inhabitants of the south of Europe have sown, for many ages, the plants of Algiers and Tunis. With the wools and cottons of the East, or of Barbary, there are often brought into France the grains of exotic plants, some of which naturalize themselves. Of this I will cite a striking example. There is, at the gate of Montpellier, a meadow set apart for drying foreign wool *after it has been washed.* There hardly passes a year without foreign plants being found naturalized in this drying-ground. I have gathered there *Centaurea parviflora*, *Psoralea palæstina*, and

* De Candolle, Essai Elémen., &c., p. 50.

† Quarterly Review, vol. xxx. p. 8.

Hypericum crispum." This fact is not only illustrative of the aid which man lends inadvertently to the propagation of plants, but it also demonstrates the multiplicity of seeds which are borne about in the woolly and hairy coats of wild animals.

The same botanist mentions instances of plants naturalized in seaports by the ballast of ships; and several examples of others which have spread through Europe from botanical gardens, so as to have become more common than many indigenous species.

It is scarcely a century, says Linnæus, since the Canadian erigeron, or flea-bane, was brought from America to the botanical garden at Paris: and already the seeds have been carried by the winds, so that it is diffused over France, the British islands, Italy, Sicily, Holland, and Germany.* Several others are mentioned by the Swedish naturalist, as having been dispersed by similar means. The common thorn-apple (*Datura Stramonium*), observes Willdenow, now grows as a noxious weed throughout all Europe, with the exception of Sweden, Lapland, and Russia. It came from the East Indies and Abyssinia to us, and was so universally spread by certain quacks, who used its seed as an emetic.†

In hot and ill-cultivated countries, such naturalizations take place more easily. Thus the *Chenopodium ambrosioides*, sown by Mr. Burchell on a point of St. Helena, multiplied so in four years as to become one of the commonest weeds in the island.‡

The most remarkable proof, says De Candolle, of

* Essay on the Habitable Earth, Amœn. Acad., vol. ii. p. 409.

† Principles of Botany, p. 389.

‡ Ibid.

the extent to which man is unconsciously the instrument of dispersing and naturalizing species, is found in the fact, that in New Holland, America, and the Cape of Good Hope, the aboriginal European species exceed in number all the others which have come from any distant regions; so that, in this instance, the influence of man has surpassed that of all the other causes which tend to disseminate plants to remote districts.

Although we are but slightly acquainted, as yet, with the extent of our instrumentality in naturalizing species, yet the facts ascertained afford no small reason to suspect, that the number which we introduce unintentionally exceeds all those transported by design. Nor is it unnatural to suppose that the functions, which the inferior beings, extirpated by man, once discharged in the economy of nature, should devolve upon the human race. If we drive many birds of passage from different countries, we are probably required to fulfil their office of carrying seeds, eggs of fish, insects, mollusks, and other creatures, to distant regions; if we extirpate quadrupeds, we must replace them, not merely as consumers of the animal and vegetable substances which they devoured, but as disseminators of plants, and of the inferior classes of the animal kingdom. I do not mean to insinuate that the very same changes which man brings about would have taken place by means of the agency of other species, but merely that he supersedes a certain number of agents; and so far as he disperses plants unintentionally, or against his will, his intervention is strictly analogous to that of the species so extirpated.

I may observe, moreover, that if, at former periods,

the animals inhabiting any given district have been partially altered by the extinction of some species, and the introduction of others, whether by new creations or by immigration, a change must have taken place in regard to the particular plants conveyed about with them to foreign countries. As, for example, when one set of migratory birds is substituted for another, the countries from and to which seeds are transported are immediately changed. Vicissitudes, therefore, analogous to those which man has occasioned, may have previously attended the springing up of new relations between species in the vegetable and animal worlds.

It may also be remarked, that if man is the most active agent in enlarging, so also is he in circumscribing the geographical boundaries of particular plants. He promotes the migration of some, he retards that of other species, so that, while in many respects he appears to be exerting his power to blend and confound the various provinces of indigenous species, he is, in other ways, instrumental in obstructing the fusion into one group of the inhabitants of contiguous provinces.

Thus, for example, when two botanical regions exist in the same great continent, such as *the European region*, comprehending the central parts of Europe and those surrounding the Mediterranean, and *the Oriental region*, as it has been termed, embracing the countries adjoining the Black Sea and the Caspian, the interposition between these of thousands of square miles of cultivated lands, opposes a new and powerful barrier against the mutual interchange of indigenous plants. Botanists are well aware that garden plants naturalize and diffuse themselves with great facility in compa-

ratively unreclaimed countries, but spread themselves slowly and with difficulty in districts highly cultivated. There are many obvious causes for this difference: by drainage and culture the natural variety of stations is diminished, and those stray individuals by which the passage of a species from one fit station to another is effected, are no sooner detected by the agriculturist, than they are uprooted as weeds. The larger shrubs and trees, in particular, can scarcely ever escape observation, when they have attained a certain size, and will rarely fail to be cut down if unprofitable.

The same observations are applicable to the interchange of the insects, birds, and quadrupeds of two regions situated like those above alluded to. No beasts of prey are permitted to make their way across the intervening arable tracts. Many birds, and hundreds of insects, which would have found some palatable food amongst the various herbs and trees of the primeval wilderness, are unable to subsist on the olive, the vine, the wheat, and a few trees and grasses favoured by man. In addition, therefore, to his direct intervention, man, in this case, operates indirectly to impede the dissemination of plants, by intercepting the migrations of animals, many of which would otherwise have been active in transporting seeds from one province to another.

Whether, in the vegetable kingdom, the influence of man will tend, after a considerable lapse of ages, to render the geographical range of *species in general* more extended, as De Candolle seems to anticipate, or whether the compensating agency above alluded to will not counterbalance the exceptions caused by our naturalizations, admits at least of some doubt. In the

attempt to form an estimate on this subject, we must be careful not to under-rate, or almost overlook, as some appear to have done, the influence of man in checking the diffusion of plants, and restricting their distribution to narrower limits.

CHAPTER VI.

LAWS WHICH REGULATE THE GEOGRAPHICAL DISTRIBUTION OF SPECIES — *continued.*

Geographical distribution of animals — Buffon on specific distinctness of quadrupeds of old and new world — Different regions of indigenous mammalia — Quadrupeds in islands — Range of the Cetacea — Dispersion of quadrupeds — their powers of swimming — Migratory instincts — Drifting of animals on ice-floes — On floating islands of drift-timber — Migrations of Cetacea — Habitations of birds — Their migrations and facilities of diffusion — Distribution of reptiles, and their powers of dissemination.

Geographical distribution of animals. — Although in speculating on "philosophical possibilities," said Buffon, "the same temperature might have been expected, all other circumstances being equal, to produce the same beings in different parts of the globe, both in the animal and vegetable kingdoms, yet it is an undoubted fact, that when America was discovered, its indigenous quadrupeds were all dissimilar to those previously known in the Old World. The elephant, the rhinoceros, the hippopotamus, the camelopard, the camel, the dromedary, the buffalo, the horse, the ass, the lion, the tiger, the apes, the baboons, and a number of other mammalia, were nowhere to be met with on the new continent; while in the old, the American species, of the same great class, were nowhere to be

seen — the tapir, the lama, the pecari, the jaguar, the couguar, the agouti, the paca, the coati, and the sloth."

These phenomena, although few in number relatively to the whole animate creation, were so striking and so positive in their nature, that the great French naturalist caught sight at once of a general law in the geographical distribution of organic beings, namely, the limitation of groups of distinct species to regions separated from the rest of the globe by certain natural barriers. It was, therefore, in a truly philosophical spirit that, relying on the clearness of the evidence obtained respecting the larger quadrupeds, he ventured to call in question the identifications announced by some contemporary naturalists of species of animals said to be common to the southern extremities of America and Africa.*

Causes which prevent the migration of animals. — The migration of quadrupeds from one part of the globe to another, observes one of our ablest writers, is prevented by uncongenial climates and the branches of the ocean which intersect continents. "Hence, by a reference to the geographical site of countries, we may divide the earth into a certain number of regions fitted to become the abodes of particular groups of animals, and we shall find, on inquiry, that each of these provinces, thus conjecturally marked out, is actually inhabited by a distinct nation of quadrupeds." †

Where the continents of the Old and New World

* Buffon, vol. v. — On the Virginian Opossum.

† Prichard's Phys. Hist. of Mankind, vol. i. p. 54. In some of the preliminary chapters will be found a sketch of the leading facts illustrative of the geographical distribution of animals, drawn up with the author's usual clearness and ability.

approximate to each other towards the north, the narrow straits which separate them are frozen over in winter, and the distance is further lessened by intervening islands. Thus a passage from one continent to another becomes practicable to such quadrupeds as are fitted to endure the intense cold of the arctic circle. Accordingly, the whole arctic region has become one of the provinces of the animal kingdom, and contains many species common to both the great continents. But the temperate regions of America, which are separated by a wide extent of ocean from those of Europe and Asia, contain each a distinct nation of indigenous quadrupeds. There are three groups of *tropical* mammalia belonging severally to America, Africa, and continental India, each inhabiting lands separated from each other by the ocean.

In Peru and Chili, says Humboldt, the region of the grasses, which is at an elevation of from 12,300 to 15,400 feet, is inhabited by crowds of lama, guanaco, and alpaca. These quadrupeds, which here represent the genus camel of the ancient continent, have not extended themselves either to Brazil or Mexico; because, during their journey, they must necessarily have descended into regions that were too hot for them.*

Marsupial quadrupeds in New Holland. — New Holland is well known to contain a most singular and characteristic assemblage of mammiferous animals, consisting of more than forty species of the marsupial family, or those furnished with a pouch under the belly for their young, of which scarcely any congeners occur elsewhere, except a few species in some islands of the

* Description of the Equatorial Regions.

Indian archipelago and the opossums of America There are, it appears, some examples of marsupial animals in the eastern hemisphere out of the Australian continent, as for instance, in New Ireland, New Guinea, and the Moluccas.

This almost exclusive occupation of the Australian continent by the kangaroos and other tribes of pouched animals, although it has justly excited great attention, is a fact, nevertheless, in strict accordance with the general laws of the distribution of species; since, in other parts of the globe, we find peculiarities of form, structure, and habit, in birds, reptiles, insects, or plants, confined entirely to one hemisphere, or one continent, and sometimes to much narrower limits.

In the south of Africa.—The southern region of Africa, where that continent extends into the temperate zone, constitutes another separate zoological province, surrounded as it is on three sides by the ocean, and cut off from the countries of milder climate, in the northern hemisphere, by the intervening torrid zone. In many instances, this region contains the same genera which are found in temperate climates to the northward of the line: but then the southern are different from the northern species. Thus, in the south we find the quagga and the zebra; in the north, the horse, the ass, and the jiggetai of Asia.

The south of Africa is spread out into fine level plains from the tropic to the Cape. In this region, says Pennant, besides the horse genus, of which five species have been found, there are also peculiar species of rhinoceros, the hog, and the hyrax, among pachydermatous races; and amongst the ruminating, the giraffe, the Cape buffalo, and a variety of remarkable antelopes,

as the springbok, the oryx, the gnou, the leucophoë, the pygarga, and several others.*

In the Indian archipelago. — The Indian archipelago presents peculiar phenomena in regard to its indigenous mammalia, which, in their generic character, recede, in some respects, from that of the animals of the Indian continent, and approximate to the African. The Sunda isles contain a hippopotamus, which is wanting in the rivers of Asia; Sumatra, a peculiar species of tapir, and a rhinoceros resembling the African more than the Indian species, but specifically distinguishable from both.†

Beyond the Indian archipelago is an extensive region, including New Guinea, New Britain, and New Ireland, together with the archipelago of Solomon's Islands, the New Hebrides, and Louisiade, and the more remote group of islands in the great southern ocean, which may be considered as forming one zoological province. Although these remarkable countries are extremely fertile in their vegetable productions, they are almost wholly destitute of native warm-blooded quadrupeds, except a few species of bats, and some domesticated animals in the possession of the natives.‡

Quadrupeds in islands. — Quadrupeds found on islands situated near the continents generally form a part of the stock of animals belonging to the adjacent mainland; but islands remote from continents, especially those of small size, are either destitute of quadrupeds, except such as have been conveyed to them

* Pennant's Hist. of Quadrupeds, cited by Prichard, Phys. Hist. of Mankind, vol. i. p. 66.

† Prichard, ibid.; Cuvier, Ann. du Muséum, tom. vii.

‡ Prichard, ibid., p. 56.

by man, or contain species peculiar to them. In the Galapagos archipelago no indigenous quadrupeds were found except one mouse, which is supposed to be distinct from any hitherto found elsewhere. A peculiar species of fox is indigenous in the Falkland Islands, and a rat in New Zealand, which last country, notwithstanding its magnitude, is destitute of other mammalia, except bats, and these, says Dr. Prichard, may have made their way along the chain of islands which extend from the shores of New Guinea far into the Southern Pacific. The same author remarks, that among the various groups of fertile islands in the Pacific, no quadrupeds have been met with except the rat and a few bats as above mentioned, and the dog and hog, which appear to have been conveyed thither by the natives from New Guinea. "Rats are to be found even on some desert islands, whither they may have been conveyed by canoes which have occasionally approached the shore. It is known, also, that rats occasionally swim in large numbers to considerable distances."*

Geographical range of the cetacea. — It is natural to suppose that the geographical range of the different species of cetacea should be less correctly ascertained than that of the terrestrial mammifers. It is, however, well known that the whales which are obtained by our fishers in the South Seas are distinct from those of the North; and the same dissimilarity has been found in all the other marine animals of the same class, so far as they have yet been studied by naturalists.

Dispersion of quadrupeds. — Let us now inquire what facilities the various land quadrupeds enjoy of spreading themselves over the surface of the earth.

* Prichard, Phys. Hist. of Mankind, vol. i. p. 75.

In the first place, as their numbers multiply, all of them, whether they feed on plants, or prey on other animals, are disposed to scatter themselves gradually over as wide an area as is accessible to them. But before they have extended their migrations over a large space, they are usually arrested either by the sea, or a zone of uncongenial climate, or some lofty and unbroken chain of mountains, or a tract already occupied by a hostile and more powerful species.

Their powers of swimming.—Rivers and narrow friths can seldom interfere with their progress; for the greater part of them swim well, and few are without this power when urged by danger and pressing want. Thus, amongst beasts of prey, the tiger is seen swimming about among the islands and creeks in the delta of the Ganges, and the jaguar traverses with ease the largest streams in South America.* The bear, also, and the bison, cross the current of the Mississippi. The popular error, that the common swine cannot escape by swimming when thrown into the water, has been contradicted by several curious and well-authenticated instances during the recent floods in Scotland. One pig, only six months old, after having been carried down from Garmouth to the bar at the mouth of the Spey, a distance of a quarter of a mile, swam four miles eastward to Port Gordon, and landed safe. Three others, of the same age and litter, swam, at the same time, five miles to the west, and landed at Blackhill.†

In an adult and wild state, these animals would doubtless have been more strong and active, and

* Buffon, vol. v. p. 204.

† Sir T. D. Lauder, Bart., on the Floods in Morayshire, Aug. 1829, p. 302. second edition.

might, when hard pressed, have performed a much longer voyage. Hence islands remote from the continent may obtain inhabitants by casualties which, like the late storms in Morayshire, may only occur once in many centuries, or thousands of years, under all the same circumstances. It is obvious that powerful tides, winds, and currents, may sometimes carry along quadrupeds capable, in like manner, of preserving themselves for hours in the sea, to very considerable distances; and in this way, perhaps, the tapir (*Tapir Indicus*) may have become common to Sumatra and the Malayan peninsula.

To the elephant, in particular, the power of crossing rivers is essential in a wild state, for the quantity of food which a herd of these animals consumes renders it necessary that they should be constantly moving from place to place. The elephant crosses the stream in two ways. If the bed of the river be hard, and the water not of too great a depth, he fords it. But when he crosses great rivers, such as the Ganges and the Niger, the elephant swims deep, so deep, that the end of his trunk only is out of the water; for it is a matter of indifference to him whether his body be completely immersed, provided he can bring the tip of his trunk to the surface, so as to breathe the external air.

Animals of the deer kind frequently take to the water, especially in the rutting season, when the stags are seen swimming for several leagues at a time, from island to island, in search of the does, especially in the Canadian lakes; and in some countries where there are islands near the sea shore, they fearlessly enter the sea and swim to them. In hunting excursions, in

North America, the elk of that country is frequently pursued for great distances through the water.

The large herbivorous animals, which are gregarious, can never remain long in a confined region, as they consume so much vegetable food. The immense herds of bisons (*Bos Americanus*) which often, in the great valleys of the Mississippi and its tributaries, blacken the surface of the prairie lands, are continually shifting their quarters, followed by wolves, which prowl about in their rear. "It is no exaggeration," says Mr. James, "to assert, that in one place, on the banks of the Platte, at least ten thousand bisons burst on our sight in an instant. In the morning, we again sought the living picture; but upon all the plain, which last evening was so teeming with noble animals, not one remained." *

Migratory instincts.— Besides the disposition common to the individuals of every species slowly to extend their range in search of food, in proportion as their numbers augment, a migratory instinct often develops itself in an extraordinary manner, when, after an unusually prolific season, or upon a sudden scarcity of provisions, great multitudes are threatened by famine. It may be useful to enumerate some examples of these migrations, because they may put us upon our guard against attributing a high antiquity to a particular species merely because it is diffused over a great space: they show clearly how soon, in a state of nature, a newly created species might spread itself, in every direction, from a single point.

In very severe winters, great numbers of the black

* Expedition from Pittsburg to the Rocky Mountains, vol. ii. p. 153.

bears of America migrate from Canada into the United States; but in milder seasons, when they have been well fed, they remain and hybernate in the north.* The rein-deer which, in Scandinavia, can scarcely exist to the south of the sixty-fifth parallel, descends, in consequence of the greater coldness of the climate, to the fiftieth degree, in Chinese Tartary, and often roves into a country of more southern latitude than any part of England.

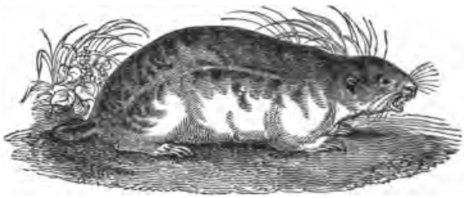
In Lapland, and other high latitudes, the common squirrels, whenever they are compelled, by want of provisions, to quit their usual abodes, migrate in amazing numbers, and travel directly forwards, allowing neither rocks and forests, nor the broadest waters, to turn them from their course. Great numbers are often drowned in attempting to pass friths and rivers. In like manner the small Norway rat sometimes pursues its migrations in a straight line across rivers and lakes; and Pennant informs us, that when the rats, in Kamtschatka, become too numerous, they gather together in the spring, and proceed in great bodies westward, swimming over rivers, lakes, and arms of the sea. Many are drowned or destroyed by water-fowl or fish. As soon as they have crossed the river Penginsk, at the head of the gulf of the same name, they turn southward, and reach the rivers Judoma and Okotsk by the middle of July; a district more than 800 miles distant from their point of departure.

The lemings, also, a small kind of rat, are described as natives of the mountains of Kolen, in Lapland; and once or twice in a quarter of a century they appear in vast numbers, advancing along the ground, and "de-

* Richardson's Fauna Boreali-Americana, p. 16.

vouring every green thing." Innumerable bands march from the Kolen, through Nordland and Finmark, to

Fig. 74.



The Leming, or Lapland Marmot (Mus Lemmus, *Linn.*)

the Western Ocean, which they immediately enter; and, after swimming about for some time, perish. Other bands take their route through Swedish Lapland, to the Bothnian Gulf, where they are drowned in the same manner. They are followed in their journeys by bears, wolves, and foxes, which prey upon them incessantly. They generally move in lines, which are about three feet from each other, and exactly parallel, going directly forward through rivers and lakes; and when they meet with stacks of hay or corn, gnawing their way through them instead of passing round.* These excursions usually precede a rigorous winter, of which the lemings seem in some way forewarned.

Vast troops of the wild ass, or *onager* of the ancients, which inhabit the mountainous deserts of Great Tartary, feed, during the summer, in the tracts east and north of Lake Aral. In the autumn they collect in herds of hundreds, and even thousands, and direct their course towards the north of India, and often to Persia, to enjoy a warm retreat during winter.† Bands

* Phil. Trans. vol. ii. p. 872.

† Wood's Zoography, vol. i. p. 11.

of two or three hundred quaggas, a species of wild ass, are sometimes seen to migrate from the tropical plains of southern Africa to the vicinity of the Malaleveen river. During their migrations they are followed by lions, who slaughter them night by night.*

The migratory swarms of the springbok, or Cape antelope, afford another illustration of the rapidity with which a species under certain circumstances may be diffused over a continent. When the stagnant pools of the immense deserts south of the Orange River dry up, which often happens after intervals of three or four years, myriads of these animals desert the parched soil, and pour down like a deluge on the cultivated regions near the Cape. The havoc committed by them resembles that of the African locusts; and so crowded are the herds, that "the lion has been seen to walk in the midst of the compressed phalanx with only as much room between him and his victims as the fears of those immediately around could procure by pressing outwards."†

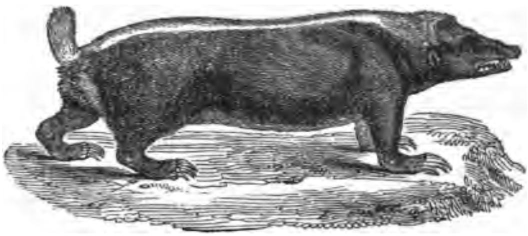
Dr. Horsfield mentions a singular fact in regard to the geographical distribution of the *Mydaus meliceps*, an animal intermediate between the polecat and badger. It inhabits Java, and is "confined exclusively to those mountains which have an elevation of more than seven thousand feet above the level of the ocean; on these it occurs with the same regularity as many plants. The long extended surface of Java, abounding with conical points which exceed this elevation, affords

* On the authority of Mr. Campbell. Library of Entert. Know., Menageries, vol. i. p. 152.

† Cuvier's Animal Kingdom by Griffiths, vol. ii. p. 109. Library of Entert. Know., Menageries, vol. i. p. 366.

many places favourable for its resort. On ascending these mountains, the traveller scarcely fails to meet with this animal, which, from its peculiarities, is universally known to the inhabitants of these elevated

Fig. 75.



Mydaus meliceps, or badger-headed Mydaus. Length, including the tail, 16 inches.

tracts, while to those of the plains it is as strange as an animal from a foreign country. In my visits to the mountainous districts, I uniformly met with it; and, as far as the information of the natives can be relied on, it is found on all the mountains."*

Now, if asked to conjecture how the Mydaus arrived at the elevated regions of each of these isolated mountains, we might say that, before the island was peopled by man, by whom their numbers are now thinned, they may occasionally have multiplied so as to be forced to collect together and migrate: in which case, notwithstanding the slowness of their motions, some few would succeed in reaching another mountain, some twenty, or even, perhaps, fifty miles distant; for although the climate of the hot intervening plains would be unfavourable to them, they might support it for a time, and would find there abundance of insects

* Horsfield, Zoological Researches in Java, No. ii., from which the figure is taken.

on which they feed. Volcanic eruptions, which, at different times, have covered the summits of some of those lofty cones with sterile sand and ashes, may have occasionally contributed to force on these migrations.

Drifting of animals on ice-floes.— The power of the terrestrial mammalia to cross the sea is very limited, and it was before stated that the same species is scarcely ever common to districts widely separated by the ocean. If there be some exceptions to this rule, they generally admit of explanation; for there are natural means whereby some animals may be floated across the water, and the sea sometimes wears a passage through a neck of land, leaving individuals of a species on each side of the new channel. Polar bears are known to have been frequently drifted on the ice from Greenland to Iceland: they can also swim to considerable distances, for Captain Parry, on the return of his ships through Barrow's Strait, met with a bear swimming in the water about midway between the shores, which were about forty miles apart, and where no ice was in sight.* "Near the east coast of Greenland," observes Scoresby, "they have been seen on ice in such quantities, that they were compared to flocks of sheep on a common; and they are often found on field-ice, above two hundred miles from the shore."† Wolves, in the arctic regions, often venture upon the ice near the shore, for the purpose of preying upon young seals, which they surprise when asleep. When these ice-floes get detached, the wolves are often carried out to sea; and though some may be drifted to islands or continents, the greater part of

* Append. to Parry's Second Voyage, years 1819–20.

† Account of the Arctic Regions, vol. i. p. 518.

them perish, and have been often heard in this situation howling dreadfully, as they die by famine.*

During the short summer which visits Melville Island, various plants push forth their leaves and flowers the moment the snow is off the ground, and form a carpet spangled with the most lively colours. These secluded spots are reached annually by herds of musk-oxen and rein-deer, which travel immense distances over dreary and desolate regions, to graze undisturbed on these luxuriant pastures.† The rein-deer often pass along in the same manner, by the chain of the Aleutian Islands, from Behring's Straits to Kamtschatka, subsisting on the moss found in these islands during their passage.‡ But the musk-ox, notwithstanding its migratory habits, and its long journeys over the ice, does not exist either in Asia or Greenland.§

On floating islands of drift-wood. — Within the tropics there are no ice-floes; but, as if to compensate for that mode of transportation, there are floating islets of matted trees, which are often borne along through considerable spaces. These are sometimes seen sailing at the distance of fifty or one hundred miles from the mouth of the Ganges, with living trees standing erect upon them. The Amazon, the Congo, and the Orinoco, also produce these verdant rafts, which are formed in the manner already described when speaking of the great raft of the Atchafalaya, an arm of the Mississippi, where a natural bridge of timber, ten miles long, and more than two hundred yards wide, existed for more than forty years, supporting a luxuriant vege-

* Turton, in a note to Goldsmith's Nat. Hist., vol. iii. p. 43.

† Supplement to Parry's First Voyage of Disc., p. 189.

‡ Godman's American Nat. Hist., vol. i. p. 22.

§ Dr. Richardson, Brit. Assoc. Reports, vol. v. p. 161.

tation, and rising and sinking with the water which flowed beneath it.

On these green islets of the Mississippi, observes Malte-Brun, young trees take root, and the pistia and nenuphar display their yellow flowers: there serpents, birds, and the cayman alligator, come to repose, and all are sometimes carried to the sea, and engulphed in its waters.*

Spix and Martius relate that, during their travels in Brazil, they were exposed to great danger while ascending the Amazon in a canoe, from the vast quantity of drift-wood constantly propelled against them by the current; so much so, that their safety depended on the crew being always on the alert to turn aside the trunks of trees with long poles. The tops alone of some trees appeared above water, others had their roots attached to them with so much soil that they might be compared to floating islets. On these, say the travellers, we saw some very singular assemblages of animals, pursuing peacefully their uncertain way in strange companionship. On one raft were several grave-looking storks, perched by the side of a party of monkeys, who made comical gestures, and burst into loud cries, on seeing the canoe. On another was seen a number of ducks and divers, sitting by a group of squirrels. Next came down, upon the stem of a large rotten cedar-tree, an enormous crocodile, by the side of a tiger-cat, both animals regarding each other with hostility and mistrust, but the saurian being evidently most at his ease, as conscious of his superior strength.†

* System of Geography, vol. v. p. 157.

† Spix and Martius, Reise, &c., vol. iii. pp. 1011. 1013.

Similar green rafts, principally composed of canes and brushwood, are called "camelotes" on the Parana in South America; and they are occasionally carried down by inundations, bearing on them the tiger, cayman, squirrels, and other quadrupeds, which are said to be always terror-stricken on their floating habitation. No less than four tigers (pumas) were landed in this manner in one night at Monte Video, lat. 35° S., to the great alarm of the inhabitants, who found them prowling about the streets in the morning.*

In a memoir lately published, a naval officer relates that, as he returned from China by the eastern passage he fell in, among the Moluccas, with several small floating islands of this kind, covered with mangrove-trees interwoven with underwood. The trees and shrubs retained their verdure, receiving nourishment from a stratum of soil which formed a white beach round the margin of each raft, where it was exposed to the washing of the waves and the rays of the sun.† The occurrence of soil in such situations may easily be explained; for all the natural bridges of timber which occasionally connect the islands of the Ganges, Mississippi, and other rivers, with their banks, are exposed to floods of water, densely charged with sediment.

Captain W. H. Smyth informs me, that, when cruising in the Cornwallis amidst the Philippine Islands, he has more than once seen, after those dreadful hur-

* Sir W. Parish's Buenos Ayres, p. 187., and Robertson's Letters on Paraguay, p. 220.

† United Service Journal, No. xxiv. p. 697.

ricanes called typhoons, floating masses of wood, with trees growing upon them; and ships have sometimes been in imminent peril, as often as these islands were mistaken for terra firma, when, in fact, they were in rapid motion.

It is highly interesting to trace, in imagination, the effects of the passage of these rafts from the mouth of a large river to some archipelago, such as those in the South Pacific, raised from the deep, in comparatively modern times, by the operations of the volcano and the earthquake, and the joint labours of coral animals and testacea. If a storm arise, and the frail vessel be wrecked, still many a bird and insect may succeed in gaining, by flight, some island of the newly formed group, while the seeds and berries of herbs and shrubs, which fall into the waves, may be thrown upon the strand. But if the surface of the deep be calm, and the rafts are carried along by a current, or wafted by some slight breath of air fanning the foliage of the green trees, it may arrive, after a passage of several weeks, at the bay of an island, into which its plants and animals may be poured out as from an ark, and thus a colony of several hundred new species may at once be naturalized.

The reader should be reminded, that I merely advert to the transportation of these rafts as of extremely rare and accidental occurrence; but it may account, in tropical countries, for some of the rare exceptions to the general law of the confined range of species.

Migrations of the cetacea.—Many of the cetacea, the whales of the northern seas for example, are found to desert one tract of the sea, and to visit another very distant, when they are urged by want of food, or danger. The seals also retire from the coast of Greenland

in July, return again in September, and depart again in March, to return in June. They proceed in great droves northwards, directing their course where the sea is most free from ice, and are observed to be extremely fat when they set out on this expedition, and very lean when they come home again.*

Species of the Mediterranean, Black Sea, and Caspian identical. — Some naturalists have wondered that the sea calves, dolphins, and other marine mammalia of the Mediterranean and Black Sea, should be identical with those found in the Caspian: and among other fanciful theories, they have suggested that they may dive through subterranean conduits, and thus pass from one sea into the other. But as the occurrence of wolves and other noxious animals, on both sides of the British Channel, was adduced, by Verstegan and Desmarest, as one of many arguments to prove that England and France were once united; so the correspondence of the aquatic species of the inland seas of Asia with those of the Black Sea tends to confirm the hypothesis, for which there are abundance of independent geological data, that those seas were connected together by straits at no remote period of the earth's history.

Geographical Distribution and Migrations of Birds.

I shall now offer a few observations on some of the other divisions of the animal kingdom. Birds, notwithstanding their great locomotive powers, form no exception to the general rules already laid down; but, in this class, as in plants and terrestrial quadrupeds,

* Krantz, vol. i. p. 129., cited by Goldsmith, Nat. Hist., vol. iii. p. 260.

different groups of species are circumscribed within definite limits. We find, for example, one assemblage in the Brazils, another in the same latitudes in Central Africa, another in India, and a fourth in New Holland. Of twenty-six different species of land birds found in the Galapagos archipelago, all, with the exception of one, are distinct from those inhabiting other parts of the globe;* and in other archipelagos a single island sometimes contains a species found in no other spot on the whole earth; as is exemplified in some of the parrot tribes. In this extensive family, which are, with few exceptions, inhabitants of tropical regions, the American group has not one in common with the African, nor either of these with the parrots of India.† Another illustration is afforded by that minute and beautiful tribe, the humming birds. The whole of them are, in the first place, peculiar to the new world; but some species are confined to Mexico, while others exist only in some of the West India Islands, and have not been found elsewhere in the western hemisphere. Yet there are species of this family which have a vast range, as the *Trochilus flammifrons* (or *Mellisuga Kingii*), which is found over a space of 2500 miles on the west coast of South America, from the hot dry country of Lima to the humid forests of Terra del Fuego. Captain King, during his survey in the years 1826—30, found this bird at the Straits of Magellan, in the month of May — the depth of winter — sucking the flowers of a large species of fuchsia, then in bloom, in the midst of a shower of snow.

The ornithology of our own country affords one well-known and striking exemplification of the law of a limited specific range; for the common grouse (*Tetrao*

* Darwin's Journal, &c., p. 461. † Prichard, vol. i. p. 47.

scoticus) occurs nowhere in the known world except in the British isles.

Some species of the vulture tribe are said to be true cosmopolites; and the common wild goose (*Anas anser*, Linn.), if we may believe some ornithologists, is a general inhabitant of the globe, being met with from Lapland to the Cape of Good Hope, frequent in Arabia, Persia, China, and Japan, and in the American continent, from Hudson's Bay to South Carolina.* An extraordinary range has also been attributed to the nightingale, which extends from western Europe to Persia, and still farther. In a work entitled Specchio Comparativo,† by Charles Bonaparte, many species of birds are enumerated as common to Rome and Philadelphia; the greater part of these are migratory, but some of them, such as the long-eared owl (*Strix otus*), are permanent in both countries. The correspondence of the ornithological fauna of the eastern and western hemispheres increases considerably, as might have been anticipated in high northern latitudes.‡

Their facilities of diffusion. — In parallel zones of the northern and southern hemispheres, a great general correspondence of form is observable, both in the aquatic and terrestrial birds; but there is rarely any specific identity: and this phenomenon is truly remarkable, when we recollect the readiness with which some birds, not gifted with great powers of flight, shift their quarters to different regions, and the facility with which others, possessing great strength of wing, perform their aërial voyage. Some migrate periodically from high latitudes, to avoid the cold of winter,

* Bewick's Birds, vol. ii. p. 294., who cites Latham.

† Pisa, 1827 (not sold).

‡ Bachman, Silliman's Amer. Journ., No. 61. p. 92.

and the accompaniments of cold, — scarcity of insects and vegetable food; others, it is said, for some particular kinds of nutriment required for rearing their young: for this purpose, they often traverse the ocean for thousands of miles, and recross it at other periods, with equal security.

Periodical migrations, no less regular, are mentioned by Humboldt, of many American water-fowl, from one part of the tropics to another in a zone where there is the same temperature throughout the year. Immense flights of ducks leave the valley of the Orinoco, when the increasing depth of its waters and the flooding of its shores prevent them from catching fish, insects, and aquatic worms. They then betake themselves to the Rio Negro and Amazon, having passed from the eighth and third degrees of north latitude to the first and fourth of south latitude, directing their course south-south-east. In September, when the Orinoco decreases and re-enters into its channel, these birds return northwards.*

The insectivorous swallows which visit our island would perish during winter, if they did not annually repair to warmer climes. It is supposed that, in these aërial excursions the average rapidity of their flight is not less than fifty miles an hour; so that, when aided by the wind, they soon reach warmer latitudes. Spallanzani calculated that the swallow can fly at the rate of ninety-two miles an hour, and conceived that the rapidity of the swift might be three times greater.† The rate of flight of the eider duck (*Anas mollissima*) is said to be ninety miles an hour; and Bachman says

* Voyage aux Régions Equinoxiales, tome vii. p. 429.

† Fleming, Phil. Zool., vol. ii. p. 43.

that the hawk, wild pigeon (*Columba migratoria*), and several species of wild ducks, in North America, fly at the rate of forty miles an hour, or nearly a thousand miles in twenty-four hours.*

When we reflect how easily different species, in a great lapse of ages, may be each overtaken by gales and hurricanes, and, abandoning themselves to the tempest, be scattered at random through various regions of the earth's surface, where the temperature of the atmosphere, the vegetation, and the animal productions, might be suited to their wants, we shall be prepared to find some species capriciously distributed, and to be sometimes unable to determine the native countries of each. Captain Smyth informs me, that, when engaged in his survey of the Mediterranean, he encountered a gale in the Gulf of Lyons, at the distance of between twenty and thirty leagues from the coast of France, which bore along many land birds of various species, some of which alighted on the ship, while others where thrown with violence against the sails. In this manner islands become tenanted by species of birds inhabiting the nearest mainland.

Geographical Distribution and Dissemination of Reptiles.

A few facts respecting the third great class of vertebrated animals will suffice to show that the plan of nature in regard to their location on the globe is perfectly analogous to that already exemplified in other parts of the organic creation, and has probably been determined by similar causes.

* Silliman's Amer. Journ., No. 61. p. 83.

Habitations of reptiles. — Of the great saurians, the gavials which inhabit the Ganges differ from the cayman of America, or the crocodile of the Nile. The monitor of New Holland is specifically distinct from the Indian species; these latter, again, from the African, and all from their congeners in the new world. So in regard to snakes; we find the boa of America represented by the python, a different though nearly allied genus in India. America is the country of the rattlesnake; Africa, of the cerastes; and Asia, of the hooded snake, or cobra di capello. The amphibious genera Siren and Menopoma belong to North America, possessing both lungs and gills, and respiring at pleasure either air or water. The only analogous animal of the old world is the *Proteus anguinus* of the lakes of Lower Carniola, and the grotto of Adelsberg between Trieste and Vienna.*

There is a legend that St. Patrick expelled all reptiles from Ireland; and certain it is that none of the three species of snakes common in England, nor the toad, have been observed there by naturalists. They have our common frog, and our water-newt, and according to Ray (Quad. 264.), the green lizard (*Lacerta viridis*).

Migrations of the larger reptiles.— The range of the large reptiles is, in general, quite as limited as that of some orders of the terrestrial mammalia. The great saurians sometimes cross a considerable tract in order to pass from one river to another; but their motions by land are generally slower than those of quadrupeds. By water, however, they may transport themselves to distant situations more easily. The larger alligator of

* Richardson, Brit. Assoc. Rep., vol. v. p. 202.

the Ganges sometimes descends beyond the brackish water of the delta into the sea; and in such cases it might chance to be drifted away by a current, and survive till it reached a shore at some distance; but such casualties are probably very rare.

Turtles migrate in large droves from one part of the ocean to another during the ovipositing season; and they find their way annually to the island of Ascension, from which the nearest land is about 800 miles distant. Dr. Fleming mentions, that an individual of the hawk's bill turtle (*Chelonia imbricata*), so common in the American seas, has been taken at Papa Stour, one of the West Zetland islands*; and, according to Sibbald, "the same animal came into Orkney." Another was taken, in 1774, in the Severn, according to Turton. Two instances, also, of the occurrence of the leathern tortoise (*C. coriacea*), on the coast of Cornwall, in 1756, are mentioned by Borlase. These animals of more southern seas can be considered only as stragglers attracted to our shores during uncommonly warm seasons by an abundant supply of food, or carried by the gulf stream, or driven by storms to high latitudes.

Some of the smaller reptiles lay their eggs on aquatic plants; and these must often be borne rapidly by rivers, and conveyed to distant regions in a manner similar to the dispersion of seeds before adverted to. But that the larger ophidians may be themselves transported across the seas, is evident from the following most interesting account of the arrival of one at the island of St. Vincent. It is worthy of being recorded, says Mr. Guilding, "that a noble specimen of the *Boa constrictor* was lately conveyed to us by the currents,

* Brit. Animals, p. 149., who cites Sibbald.

twisted round the trunk of a large sound cedar tree, which had probably been washed out of the bank by the floods of some great South American river, while its huge folds hung on the branches, as it waited for its prey. The monster was fortunately destroyed after killing a few sheep, and his skeleton now hangs before me in my study, putting me in mind how much reason I might have had to fear in my future rambles through the forests of St. Vincent, had this formidable reptile been a pregnant female, and escaped to a safe retreat."*

* Zool. Journ. vol. iii. p. 406. Dec. 1827.

CHAPTER VII.

LAWS WHICH REGULATE THE GEOGRAPHICAL DISTRIBUTION OF SPECIES — *continued.*

Geographical distribution and migrations of fish — of testacea — of zoophytes — Distribution of insects — Migratory instincts of some species — Certain types characterize particular countries — Their means of dissemination — Geographical distribution and diffusion of man — Speculations as to the birth-place of the human species — Progress of human population — Drifting of canoes to vast distances — On the involuntary influence of man in extending the range of many other species.

Geographical Distribution and Migrations of Fish.

Although we are less acquainted with the habitations of marine animals than with the grouping of the terrestrial species before described, yet it is well ascertained that their distribution is governed by the same general laws. The testimony borne by MM. Péron and Lesueur to this important fact is remarkably strong. These eminent naturalists, after collecting and describing many thousand species of marine animals which they brought to Europe from the southern hemisphere, insist most emphatically on their distinctness from those north of the equator; and this remark they extend to animals of all classes, from those of a more simple to those of a more complex organization — from the sponges and medusæ to the cetacea. "Among all those which we have been able so examine," say

they, "with our own eyes, or with regard to which it has appeared to us possible to pronounce with certainty, there is not a single animal of the southern regions which is not distinguished by essential characters from the analogous species in the northern seas." *

On comparing the fresh-water fish of Europe and North America, Dr. Richardson remarks, that the only species which is unequivocally common to the two continents is the pike (*Esox lucius*); and it is curious that this fish is unknown to the westward of the Rocky Mountains, the very coast which approaches nearest to the old continent.†

The fish of the Arabian Gulf are said to differ entirely from those of the Mediterranean, notwithstanding the proximity of these seas. The flying-fish are found (some stragglers excepted) only between the tropics; in receding from the line, they never approach a higher latitude than the fortieth parallel. Those inhabiting the Atlantic are said to be different species from those of the eastern ocean.‡ The electric gymnotus belongs exclusively to America; the trembler, or *Silurus electricus*, to the rivers of Africa; but the torpedo, or cramp-fish, is said to be dispersed over all tropical, and many temperate seas.§

All are aware that there are certain fish of passage which have their periodical migrations, like some tribes of birds. The salmon, towards the season of spawning, ascends the rivers for hundreds of miles, leaping up the cataracts which it meets in its course, and then retreats again into the depths of the ocean. The her-

* Sur les Habitations des Animaux Marins.— Ann. du Mus., tom. xv. cited by Prichard, Phys. Hist. of Mankind, vol. i. p. 51.

† Brit. Assoc. Reports, vol. v. p. 203.

‡ Malte-Brun, vol. i. p. 507. § Ibid.

ring and the haddock, after frequenting certain shores, in vast shoals, for a series of years, desert them again, and resort to other stations, followed by the species which prey on them. Eels are said to descend into the sea for the purpose of producing their young, which are seen returning into the fresh water by myriads, extremely small in size, but possessing the power of surmounting every obstacle which occurs in the course of a river, by applying their slimy and glutinous bodies to the surface of rocks, or the gates of a lock, even when dry, and so climbing over it.* Before the year 1800 there were no eels in Lake Wener, the largest inland lake in Sweden, which discharges its waters by the celebrated cataracts of Trolhättan. But I am informed by Professor Nilsson that since the canal was opened uniting the river Gotha with the lake by a series of nine locks, each of great height, eels have been observed in abundance in the lake. It appears, therefore, that though they were unable to ascend the falls, they have made their way by the locks, by which in a very short space a difference of level of 114 feet is overcome.

Gmelin says, that the anseres (wild geese, ducks, and others) subsist, in their migrations, on the spawn of fish; and that oftentimes, when they void the spawn, two or three days afterwards, the eggs retain their vitality unimpaired.† When there are many disconnected fresh-water lakes in a mountainous region, at various elevations, each remote from the other, it has often been deemed inconceivable how they could all become stocked with fish from one common source; but it has been suggested, that the minute eggs of

* Phil. Trans. 1747, p. 395. † Amoen. Acad., Essay 75.

these animals may sometimes be entangled in the feathers of water-fowl. These, when they alight to wash and plume themselves in the water, may often unconsciously contribute to propagate swarms of fish, which, in due season, will supply them with food. Some of the water-beetles, also, as the dyticidæ, are amphibious, and in the evening quit their lakes and pools; and, flying in the air, transport the minute ova of fishes to distant waters. In this manner some naturalists account for the fry of fish appearing occasionally in small pools caused by heavy rains; but the showers of small fish, stated in so many accounts to have fallen from the atmosphere, require further investigation.

Geographical Distribution and Migrations of Testacea.

The testacea, of which so great a variety of species occurs in the sea, are a class of animals of peculiar importance to the geologist; because their remains are found in strata of all ages, and generally in a higher state of preservation than those of other organic beings. Climate has a decided influence on the geographical distribution of species in this class; but as there is much greater uniformity of temperature in the waters of the ocean, than in the atmosphere which invests the land, the diffusion of many marine mollusks is extensive.

Causes which limit the extension of many species.— Some forms attain their fullest development in warm latitudes; and are often exclusively confined to the torrid zone, as *Nautilus*, *Harpa*, *Terebellum*, *Pyramidella*, *Delphinula*, *Aspergillum*, *Tridacna*, *Cucullæa*,

Crassatella, *Corbis*, *Perna*, and *Plicatula*. Other forms are limited to one region of the sea, as the *Trigonia* to parts of Australia, and the *Concholepas* to the western coast of South America, where the shells differ almost entirely from those on the eastern coast of the same continent. Such being the case, it is not wonderful that we find an entire difference between the South American shells and those of the Indian archipelago in the same latitude. On the shores of many of the islands of the South Pacific peculiar species have been obtained. Péron and Lesueur remark, that the *Haliotis gigantea* of Van Diemen's Land, and the *Phasianella*, diminish in size as they follow the coasts of New Holland, northwards to King George's Sound, and entirely disappear beyond them.* But we are as yet by no means able to sketch out the submarine provinces of shells, as the botanist has done those of the terrestrial, and even of the subaqueous plants. There can be little doubt, however, that the boundaries in this case, both of latitude and longitude, will be found in general well defined. The continuous lines of continents, stretching from north to south, prevent a particular species from belting the globe, and following the direction of the isothermal lines. The inhabitants of the West Indian seas, for example, cannot enter the Pacific, without passing round through the inclement climate of Cape Horn. Currents also flowing permanently in certain directions, and the influx at certain points of great bodies of fresh water, limit the extension of many species. Those which love deep water are arrested by shoals; others, fitted for shallow seas, cannot migrate across unfathomable abysses.

* Ann. du Mus. d'Hist. Nat. tom. xv.

Great range of some species.— Some few species, however, have an immense range, as the *Sanguinolaria rugosa*, Lamk., which is found in the West Indies, Brazil, the Red Sea, Tranquebar, the Chinese sea, and in the island of Annaa, one of the South Sea islands, where it was discovered by Mr. Cuming.* The *Cypræa moneta*, a Mediterranean shell, occurs also in South Africa, the Isle of France, the East Indies, in China, the South Sea, and even as far west as Otaheite. The *Turbo petræus* inhabits the seas of England, Guadaloupe, and the Cape of Good Hope.†

The *Ianthina fragilis* has wandered into almost every sea, both tropical and temperate. This "common oceanic snail" derives its buoyancy from an admirably contrived float, which has enabled it not only to disperse itself so universally, but to become an active agent in disseminating other species, which attach themselves, or their ova, to its shell.‡

It is evident that, among the testacea, as in plants and the higher order of animals, there are species which have a power of enduring a wide range of temperature, whereas others cannot resist a considerable change of climate. Among the fresh-water mollusks, and those which breathe air, Férussac mentions a few instances of species of almost universal diffusion.

The *Helix putris* (*Succinea putris*, Lam.), so com-

* On the authority of Dr. Beck.

† Fér. art. Géogr. Phys. Dict. Class. d'Hist. Nat.

‡ Mr. Broderip possesses specimens of *Ianthina fragilis*, bearing more than one species of barnacle (*Pentelasmis*,) presented to him by Captain King and Lieutenant Graves. One of these specimens, taken alive by Captain King far at sea, and a little north of the equator, is so loaded with those cirrhipeds, and with numerous ova, that all the upper part of its shell is invisible.

mon in Europe, where it reaches from Norway to Italy, is also found in Egypt, in the United States, in Newfoundland, Jamaica, Tranquebar, and, it is even said, in the Marianne Isles. As this animal inhabits constantly the borders of pools and streams where there is much moisture, it is not impossible that different water-fowl have been the agents of spreading some of its minute eggs, which may have been entangled in their feathers. *Helix aspersa*, one of the commonest of our larger land-shells, is found in South America, at the foot of Chimborazo, as also in Cayenne, and in St. Helena. Some conchologists have conjectured that it was accidentally imported in some ship; for it is an eatable species, and these animals are capable of retaining life during long voyages, without air or nourishment.*

Confined range of others.— Mr. Lowe, in a memoir published in the Cambridge Transactions in 1831, enumerates seventy-one species of land mollusca, collected by him in the islands of Madeira and Porto Santo, sixty of which belonged to the genus Helix alone, including as sub-genera Bulimus and Achatina, and excluding Vitrina and Clausilia; — forty-four of these are new. It is remarkable, that very few of the above-

* Four individuals of a large species of land-shell (*Bulimus*), from Valparaiso, were brought to England by Lieutenant Graves, who accompanied Captain King in his late expedition to the Straits of Magellan. They had been packed up in a box, and enveloped in cotton: two for a space of thirteen, one for seventeen, and a fourth for upwards of twenty months; but, on being exposed by Mr. Broderip to the warmth of a fire in London, and provided with tepid water and leaves, they revived, and lived for several months in Mr. Loddiges' palm-house, till accidentally drowned.

mentioned species are common to the neighbouring archipelago of the Canaries; but it is a still more striking fact, that, of the sixty species of the three genera abovementioned, thirty-one are natives of Porto Santo; whereas, in Madeira, which contains ten times the superficies, were found but twenty-nine. Of these only four were common to the two islands, which are separated by a distance of only twelve leagues; and two even of these four (namely, *Helix rhodostoma* and *H. ventrosa*) are species of general diffusion, common to Madeira, the Canaries, and the South of Europe.*

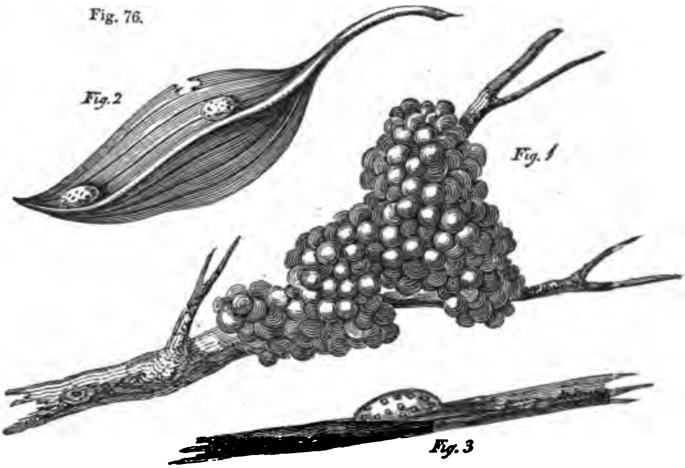
The confined range of these mollusks may easily be explained, if we admit that species have only one birth-place; and the only problem to be solved would relate to the exceptions — to account for the dissemination of some species throughout several islands, and the European continent. May not the eggs, when washed into the sea by the undermining of cliffs, or blown by a storm from the land, float uninjured to a distant shore?

Their mode of diffusion.— Notwithstanding the proverbially slow motion of snails and mollusks in general, and although many aquatic species adhere constantly to the same rock for their whole lives, they are by no means destitute of provision for disseminating themselves rapidly over a wide area. Some lay their eggs in a sponge-like nidus, wherein the young remain enveloped for a time after their birth; and this buoyant substance floats far and wide as readily as sea-weed. The young of other viviparous tribes are often borne along, entangled in sea-weed. Sometimes they are so light, that, like grains of sand, they can be

* Camb. Phil. Trans. vol. iv. 1831.

easily moved by currents. Balani and serpulæ are sometimes found adhering to floating cocoa-nuts, and even to fragments of pumice. In rivers and lakes, on

Fig. 76.



Eggs of fresh-water Mollusks.

Fig. 1. Eggs of *Ampullaria ovata* (a fluviatile species,) fixed to a small sprig which had fallen into the water.
Fig. 2. Eggs of *Planorbis albus*, attached to a dead leaf lying under water.
Fig. 3. Eggs of the common Limneus (*L. vulgaris*), adhering to a dead stick under water.

the other hand, aquatic univalves usually attach their eggs to leaves and sticks which have fallen into the water, and which are liable to be swept away during floods, from tributaries to the main streams, and from thence to all parts of the same basins. Particular species may thus migrate during one season from the head waters of the Mississippi, or any other great river, to countries bordering the sea, at the distance of many thousand miles.

An illustration of the mode of attachment of these eggs will be seen in the annexed cut. (Fig. 76.)

The habit of some testacea to adhere to floating wood is proved by their fixing themselves to the bottoms of ships. By this mode of conveyance *Mytilus polymorphus*, previously known only in the Danube and Wolga, may have been brought to the Commercial Docks in the Thames, and to Hamburg, where the species is now domiciled. But Mr. Gray suggests that as the animal is known to have the faculty of living for a very long time out of water, it is more probable that it was brought in Russian timber than borne uninjured through the salt-water at the bottom of a vessel.*

A lobster (*Astacus marinus*) was lately taken alive covered with living mussels (*Mytilus edulis*)†; and a large female crab (*Cancer pagurus*), covered with oysters, and bearing also *Anomia ephippium*, and actiniæ, was taken in April, 1832, off the English coast. The oysters, seven in number, include individuals of six years' growth, and the two largest are four inches long and three inches and a half broad. Both the crab and the oysters were seen alive by Mr. Robert Brown.‡

From this example we learn the manner in which

* Phil. Trans. 1835, p. 303.

† The specimen is preserved in the Museum of the Zool. Soc. of London.

‡ This specimen is in the collection of my friend Mr. Broderip, who observes, that this crab, which was apparently in perfect health, could not have cast her shell for six years, whereas some naturalists have stated that the species moults annually, without limiting the moulting period to the early stages of growth of the animal.

oysters may be diffused over every part of the sea where the crab wanders; and if they are at length carried to a spot where there is nothing but fine mud, the foundation of a new oyster-bank may be laid on the death of the crab. In this instance the oysters survived the crab many days, and were killed at last only by long exposure to the air.

Geographical Distribution and Migrations of Zoopyhtes.

Zoophytes are very imperfectly known, but there can be little doubt that each maritime region possesses species peculiar to itself. The madrepores, or lamelliferous polyparia, are found in their fullest development only in the tropical seas of Polynesia and the East and West Indies; and this family is represented only by a few species in our seas. Those even of the Mediterranean are inferior in size; and, for the most part, different from such as inhabit the tropics. Péron and Lesueur, after studying the Holothuriæ, Medusæ, and other congeners of delicate and changeable forms, came to the conclusion that each kind has its place of residence determined by the temperature necessary to support its existence. Thus, for example, they found the abode of ***Pyrosoma Atlantica*** to be confined to one particular region of the Atlantic Ocean.*

Let us now inquire how the transportation of polyps from one part of the globe to another is effected. Many of them, as in the families Flustra and Sertularia, attach themselves to sea-weed, and are occasionally drifted along with it. Many fix themselves to the shells of mollusca, and are thus borne along by

* Voy. aux Terres Australes, tome i. p. 492.

them to short distances. Some polyps, like some species of sea-pens, float about in the ocean, and are usually believed to possess powers of spontaneous motion. But the most frequent mode of transportation consists in the buoyancy of their eggs, or certain small vesicles, which are detached, and are capable of becoming the foundation of a new colony. These gems, as they are called, have, in many instances, a locomotive power of their own, by which they proceed in a determinate direction for several days after separation from the parent. They are propelled by means of numerous short threads or *ciliæ*, which are in constant and rapid vibration; and, when thus supported in the water, they may be borne along by currents to a great distance.

That some zoophytes adhere to floating bodies, is proved by their being found attached to the bottoms of ships, like certain testacea before alluded to.

Geographical Distribution and Migrations of Insects.

Before I conclude this sketch of the manner in which the habitable parts of the earth are shared out among particular assemblages of organic beings, I must offer a few remarks on insects, which, by their numbers and the variety of their powers and instincts, exert a prodigious influence in the economy of animate nature. As a large portion of these minute creatures are strictly dependent for their subsistence on certain species of vegetables, the entomological provinces must coincide in a considerable degree with the botanical.

All the insects, says Latreille, brought from the eastern parts of Asia and China, whatever be their

latitude and temperature, are distinct from those of Europe and of Africa. The insects of the United States, although often they approach very close to our own, are nevertheless specifically distinguishable by some characters. In South America, the equinoctial lands of New Granada and Peru on the one side, and of Guiana on the other, contain for the most part distinct groups; the Andes forming the division, and interposing a narrow line of severe cold between climates otherwise very similar.*

Migratory instincts. — The insects of the United States, even those of the northern provinces as far as Canada, differ specifically from the European; while those of Greenland appear to be in a great measure identical with our own. Some insects are very local; while a few, on the contrary, are common to remote countries, between which the torrid zone and the ocean intervene. Thus our painted lady butterfly (*Vanessa cardui*) re-appears at the Cape of Good Hope and in New Holland and Japan with scarcely a varying streak.† The same species is said to be one of the few insects which are universally dispersed over the earth, being found in Europe, Asia, Africa, and America; and its wide range is the more interesting, because it seems explained by its migratory instinct, seconded, no doubt, by a capacity, enjoyed by few species, of enduring a great diversity of temperature.

A vast swarm of this species, forming a column from ten to fifteen feet broad, was, a few years since, observed in the Canton de Vaud; they traversed the

* Géographie Genérale des Insectes et des Arachnides. Mém. du Mus. d'Hist. Nat. tome iii.

† Kirby and Spence, vol. iv. p. 487.; and other authors.

country with great rapidity from north to south, all flying onwards in regular order, close together, and not turning from their course on the approach of other objects. Professor Bonelli, of Turin, observed in March of the same year, a similar swarm of the same species, also directing their flight from north to south, in Piedmont, in such immense numbers that at night the flowers were literally covered with them. They had been traced from Coni, Raconi, Susa, &c. A similar flight at the end of the last century is recorded by M. Louch, in the Memoirs of the Academy of Turin. The fact is the more worthy of notice, because the caterpillars of this butterfly are not gregarious, but solitary from the moment that they are hatched; and this instinct remains dormant, while generation after generation passes away, till it suddenly displays itself in full energy when their numbers happen to be in excess.

Not only peculiar species, but certain types, distinguish particular countries; and there are groups, observes Kirby, which represent each other in distant regions, whether in their form, their functions, or in both. Thus the honey and wax of Europe, Asia, and Africa, are in each case prepared by bees congenerous with our common hive-bee (*Apis*, Latr.); while, in America, this genus is nowhere indigenous, but is replaced by Melipona, Trigona, and Euglossa; and in New Holland by a still different, but undescribed type.* The European bee (*Apis mellifica*), although not a native of the new world, is now established, both in North and South America. It was introduced into the United States by some of the early settlers, and

* Kirby and Spence, vol. iv. p. 497.

has since overspread the vast forests of the interior, building hives in the decayed trunks of trees. "The Indians," says Irving, "consider them as the harbinger of the white man as the buffalo is of the red man, and say that in proportion as the bee advances the Indian and the buffalo retire. It is said," continues the same writer, "that the wild bee is seldom to be met with at any great distance from the frontier, and that they have always been the heralds of civilization, preceding it as it advanced from the Atlantic borders. Some of the ancient settlers of the west even pretend to give the very year when the honey-bee first crossed the Mississippi.*

As almost all insects are winged, they can readily spread themselves wherever their progress is not opposed by uncongenial climates, or by seas, mountains, and other physical impediments; and these barriers they can sometimes surmount by abandoning themselves to violent winds, which, as I before stated, when speaking of the dispersion of seeds (p. 98.), may in a few hours carry them to very considerable distances. On the Andes some sphinxes and flies have been observed by Humboldt, at the height of 19,180 feet above the sea, and which appeared to him to have been involuntarily carried into these regions by ascending currents of air.†

White mentions a remarkable shower of aphides which seem to have emigrated, with an east wind, from the great hop plantations of Kent and Sussex, and blackened the shrubs and vegetables where they alighted at Selborne, spreading at the same time in

* Washington Irving's Tour in the Prairies, ch. ix.

† Description of the Equatorial Regions — Malte-Brun, vol. v. p. 379.

great clouds all along the vale from Farnham to Alton. These aphides are sometimes accompanied by vast numbers of the common lady-bird (*Coccinella septem-punctata*), which feed upon them.*

It is remarkable, says Kirby, that many of the insects which are occasionally observed to emigrate, as, for instance, the libellulæ, coccinellæ, carabi, cicadæ, &c. are not usually social insects; but seem to congregate, like swallows, merely for the purpose of emigration.† Here, therefore, we have an example of an instinct developing itself on certain rare emergencies, causing unsocial species to become gregarious, and to venture sometimes even to cross the ocean.

The armies of locusts which darken the air in Africa and traverse the globe from Turkey to our southern counties in England, are well known to all. When the western gales sweep over the Pampas, they bear along with them myriads of insects of various kinds. As a proof of the manner in which species may be thus diffused, I may mention that when the Creole frigate was lying in the outer roads off Buenos Ayres, in 1819, at the distance of six miles from the land, her decks and rigging were suddenly covered with thousands of flies and grains of sand. The sides of the vessel had just received a fresh coat of paint, to which the insects adhered in such numbers as to spot and disfigure the vessel, and to render it necessary partially to renew the paint.‡ Captain W. H. Smyth was obliged to repaint his vessel, the Adventure, in the Mediterranean, from the same cause. He was on his way from Malta to Tripoli, when a southern wind

* Kirby and Spence, vol. ii. p. 9. 1817. ‡ Ibid. p. 12.

‡ I am indebted to Lieutenant Graves, R. N., for this information.

blowing from the coast of Africa, then one hundred miles distant, drove such myriads of flies upon the fresh paint, that not the smallest point was left unoccupied by insects.

To the southward of the river Plata, off Cape St. Antonio, and at the distance of fifty miles from land, several large dragon-flies alighted on the Adventure frigate, during Captain King's late expedition to the Straits of Magellan. If the wind abates when insects are thus crossing the sea, the most delicate species are not necessarily drowned; for many can repose without sinking on the water. The slender long-legged tipulæ have been seen standing on the surface of the sea, when driven out far from our coast, and took wing immediately on being approached.* Exotic beetles are sometimes thrown on our shore, which revive after having been long drenched in salt water; and the periodical appearance of some conspicuous butterflies amongst us, after being unseen for five or fifty years, has been ascribed, not without probability, to the agency of the winds.

Inundations of rivers, observes Kirby, if they happen at any season except in the depth of winter, always carry down a number of insects, floating on the surface of bits of stick, weeds, &c.; so that when the waters subside, the entomologist may generally reap a plentiful harvest. In the dissemination, moreover, of these minute beings, as in that of plants, the larger animals play their part. Insects are, in numberless instances, borne along in the coats of animals, or the feathers of birds; and the eggs of some species are capable, like seeds, of resisting the digestive

* I state this fact on the authority of my friend, Mr. John Curtis.

powers of the stomach, and after they are swallowed with herbage, may be ejected again unharmed in the dung.

Geographical Distribution and Diffusion of Man.

I have reserved for the last some observations on the range and diffusion of the human species over the earth, and the influence of man in spreading other animals and plants, especially the terrestrial.

Many naturalists have amused themselves in speculating on the probable birth-place of mankind, the point from which, if we assume the whole human race to have descended from a single pair, the tide of emigration must originally have proceeded. It has been always a favourite conjecture, that this birth-place was situated within or near the tropics, where perpetual summer reigns, and where fruits, herbs, and roots are plentifully supplied throughout the year. The climate of these regions, it has been said, is suited to a being born without any covering, and who had not yet acquired the arts of building habitations or providing clothes.

Progress of human population.—"The hunter state," it has been argued, "which Montesquieu placed the first, was probably only the second stage to which mankind arrived; since so many arts must have been invented to catch a salmon, or a deer, that society could no longer have been in its infancy when they came into use." * When regions where the spontaneous fruits of the earth abound became overpeopled, men would naturally diffuse themselves over the neighbouring parts of the temperate zone; but a consider-

* Brand's Select Dissert. from the Amœn. Acad. vol. i. p. 118.

able time would probably elapse before this event took place; and it is possible, as a writer before cited observes, that in the interval before the multiplication of their numbers and their increasing wants had compelled them to emigrate, some arts to take animals were invented, but far inferior to what we see practised at this day among savages. As their habitations gradually advanced into the temperate zone, the new difficulties they had to encounter would call forth by degrees the spirit of invention, and the probability of such inventions always rises with the number of people involved in the same necessity.*

A distinguished modern writer, who coincides for the most part in the views above mentioned, has introduced one of the persons in his second dialogue as objecting to the theory of the human race having gradually advanced from a savage to a civilized state, on the ground that "the first man must have inevitably been destroyed by the elements or devoured by savage beasts, so infinitely his superiors in physical force."† He then contends against the difficulty here started by various arguments, all of which were, perhaps, superfluous; for if a philosopher is pleased to indulge in conjectures on this subject, why should he not assign, as the original seat of man, some one of those large islands within the tropics, which are as free from large beasts of prey as Van Diemen's Land or Australia? Here man may have remained for a period, peculiar to a single island, just as some of the large anthropomorphous species are now limited to one island within the tropics. In such a situation, the new-born race might

* Brand's Select Dissert. from the Amœn. Acad. vol. i. p. 118.

† Sir H. Davy, Consolations in Travel, p. 74.

have lived in security, though far more helpless than the New Holland savages, and might have found abundance of vegetable food. Colonies may afterwards have been sent forth from this mother country, and then the peopling of the earth may have proceeded according to the hypothesis before alluded to.

In an early stage of society the necessity of hunting acts as a principle of repulsion, causing men to spread with the greatest rapidity over a country, until the whole is covered with scattered settlements. It has been calculated that eight hundred acres of hunting-ground produce only as much food as half an acre of arable land. When the game has been in a great measure exhausted, and a state of pasturage succeeds, the several hunter tribes, being already scattered, may multiply in a short time into the greatest number which the pastoral state is capable of sustaining. The necessity, says Brand, thus imposed upon the two savage states, of dispersing themselves far and wide over the country, affords a reason why, at a very early period, the worst parts of the earth may have become inhabited.

But this reason, it may be said, is only applicable in as far as regards the peopling of a continuous continent; whereas the smallest islands, however remote from continents, have almost always been found inhabited by man. St. Helena, it is true, afforded an exception; for when that island was discovered in 1501, it was only inhabited by sea-fowl, and occasionally by seals and turtles, and was covered with a forest of trees and shrubs, all of species peculiar to it, with one or two exceptions, and which seem to have been expressly created for this remote and insulated spot.*

* See p. 90.

The islands also of Mauritius, Bourbon, Pitcairns, and Juan Fernandez, and those of the Galapagos archipelago, one of which is seventy miles long, were uninhabited when first discovered, and what is more remarkable than all, the Falkland Islands, which together are 120 miles in length by 60 in breadth, and abounding in food fit for the support of man.

Drifting of canoes to vast distances.— But very few of the numerous coral islets and volcanos of the vast Pacific, capable of sustaining a few families of men, have been found untenanted; and we have, therefore, to inquire whence and by what means, if all the members of the great human family have had one common source, could those savages have migrated. Cook, Forster, and others, have remarked that parties of savages in their canoes must often have lost their way, and must have been driven on distant shores, where they were forced to remain, deprived both of the means and of the requisite intelligence for returning to their own country. Thus Captain Cook found on the island of Wateoo three inhabitants of Otaheite, who had been drifted thither in a canoe, although the distance between the two isles is 550 miles. In 1696, two canoes, containing thirty persons, who had left Ancorso, were thrown by contrary winds and storms on the island of Samar, one of the Philippines, at a distance of 800 miles. In 1721, two canoes, one of which contained twenty-four, and the other six persons, men, women, and children, were drifted from an island called Farroilep to the island of Guaham, one of the Marians, a distance of 200 miles.*

Kotzebue, when investigating the Coral Isles of

* Malte-Brun's Geography, vol. iii. p. 419.

Radack, at the eastern extremity of the Caroline Isles, became acquainted with a person of the name of Kadu, who who a native of Ulea, an isle 1500 miles distant, from which he had been drifted with a party. Kadu and three of his countrymen one day left Ulea in a sailing boat, when a violent storm arose, and drove them out of their course; they drifted about the open sea for eight months, according to their reckoning by the moon, making a knot on a cord at every new moon. Being expert fishermen, they subsisted entirely on the produce of the sea; and when the rain fell, laid in as much fresh water as they had vessels to contain it. "Kadu," says Kotzebue, "who was the best diver, frequently went down to the bottom of the sea, where it is well known that the water is not so salt, with a cocoa-nut shell, with only a small opening." * When these unfortunate men reached the isles of Radack, every hope and almost every feeling had died within them; their sail had long been destroyed, their canoe had long been the sport of winds and waves, and they were picked up by the inhabitants of Aur in a state of insensibility; but by the hospitable care of those islanders they soon recovered, and were restored to perfect health.†

Captain Beechey, in his late voyage to the Pacific, fell in with some natives of the Coral Islands, who had in a similar manner been carried to a great distance from their native country. They had embarked, to the

* Chamisso states that the water which they brought up was cooler, and, *in their opinion*, less salt. It is difficult to conceive its being fresher near the bottom, except where submarine springs may happen to rise.

† Kotzebue's Voyage, 1815—1818. Quarterly Review, vol. xxvi. p. 361.

number of 150 souls, in three double canoes, from Anaa, or Chain Island, situated about three hundred miles to the eastward of Otaheite. They were overtaken by the monsoon, which dispersed the canoes; and after driving them about the ocean, left them becalmed, so that a great number of persons perished. Two of the canoes were never heard of, but the other was drifted from one uninhabited island to another, at each of which the voyagers obtained a few provisions; and at length, after having wandered for a distance of 600 miles, they were found and carried to their home in the Blossom.*

Mr. Crawfurd informs me that there are several well authenticated accounts of canoes having been drifted from Sumatra to Madagascar, and by such causes a portion of the Malayan language, with some useful plants, have been transferred to that island, which is principally peopled by negroes.

The space traversed in some of these instances was so great, that similar accidents might suffice to transport canoes from various parts of Africa to the shores of South America, or from Spain to the Azores, and thence to North America; so that man, even in a rude state of society, is liable to be scattered involuntarily by the winds and waves over the globe, in a manner singularly analogous to that in which many plants and animals are diffused. We ought not, then to wonder, that during the ages required for some tribes of the human race to attain that advanced stage of civilization which empowers the navigator to cross the ocean in all directions with security, the whole earth should have

* Narrative of a Voyage to the Pacific, &c., in the years 1825, 1826, 1827, 1828, p. 170.

become the abode of rude tribes of hunters and fishers. Were the whole of mankind now cut off, with the exception of one family, inhabiting the old or new continent, or Australia, or even some coral islet of the Pacific, we might expect their descendants, though they should never become more enlightened than the South Sea Islanders or the Esquimaux, to spread in the course of ages over the whole earth, diffused partly by the tendency of population to increase, in a limited district, beyond the means of subsistence, and partly by the accidental drifting of canoes by tides and currents to distant shores.

Involuntary Influence of Man in diffusing animals and Plants.

Many of the general remarks which have been made respecting the influence of man in spreading or in checking the diffusion of plants, apply equally to his relations with the animal kingdom. On a future occasion, I shall be led to speak of the instrumentality of our species in naturalizing useful animals and plants in new regions, when explaining my views of the effects which the spreading and increase of certain species exert in the extirpation of others. At present I shall confine myself to a few remarks on the involuntary aid which man lends to the dissemination of species.

In the mammiferous class our influence is chiefly displayed in increasing the number of quadrupeds which are serviceable to us, and in exterminating or reducing the number of those which are noxious.

Sometimes, however, we unintentionally promote the multiplication of inimical species, as when we introduced the rat, which was not indigenous in the new

world, into all parts of America. They have been conveyed over in ships, and now infest a great multitude of islands and parts of that continent. In like manner the Norway rat has been imported into England, where it plunders our property in ships and houses.

Among birds, the house sparrow may be cited as a species known to have extended its range with the tillage of the soil. During the last century it has spread gradually over Asiatic Russia towards the north and east, always following the progress of cultivation. It made its first appearance on the Irtisch in Tobolsk, soon after the Russians had ploughed the land. It came in 1735 up the Obi to Beresow, and four years after to Naryn, about fifteen degrees of longitude farther east. In 1710, it had been seen in the higher parts of the coast of the Lena, in the government of Irkutzk. In all these places it is now common, but is not yet found in the uncultivated regions of Kamtschatka.*

The great viper (*Fer de lance*), a species no less venomous than the rattle-snake, which now ravages Martinique and St. Lucia, was accidentally introduced by man, and exists in no other part of the West Indies.

Many parasitic insects which attack our persons, and some of which are supposed to be peculiar to our species, have been carried into all parts of the earth, and have as high a claim as man to a *universal* geographical distribution.

* Gloger, Abänd. der Vögel, p. 103.; Pallas, Zoog. Rosso-Asiat. tom. ii. p. 197.

A great variety of insects have been transported in ships from one country to another, especially in warmer latitudes. Notwithstanding the coldness of our climate, we have been unable to prevent the cockroach (*Blatta orientalis*) from entering and diffusing itself in our ovens and kneading troughs, and availing itself of the artificial warmth which we afford. It is well known also that beetles, and many other kinds of ligniperdous insects, have been introduced into Great Britain in timber; especially several North American species. "The commercial relations," says Malte-Brun*, "between France and India, have transported from the latter country the aphis, which destroys the apple-tree, and two sorts of Neuroptera, the *lucifuga* and *flavicola*, mostly confined to Provence and the neighbourhood of Bourdeaux, where they devour the timber in the houses and naval arsenals."

Among mollusks we may mention the *Teredo navalis*, which is a native of equatorial seas, but which, by adhering to the bottom of ships, was transported to Holland, where it has been most destructive to vessels and piles. The same species has also become naturalized in England, and other countries enjoying an extensive commerce. *Bulimus undatus*, a land species of considerable size, native of Jamaica and other West Indian islands, has been imported, adhering to tropical timber, into Liverpool; and, as I learn from Mr. Broderip, is now naturalized in the woods near that town.

In all these and innumerable other instances we may regard the involuntary agency of man as strictly

* Syst. of Geog. vol. viii. p. 169.

analogous to that of the inferior animals. Like them, we unconsciously contribute to extend or limit the geographical range and numbers of certain species, in obedience to general rules in the economy of nature, which are for the most part beyond our control.

CHAPTER VIII.

THEORIES RESPECTING THE ORIGINAL INTRODUCTION OF SPECIES.

Proposal of an hypothesis on this subject — Supposed centres or foci of creation — Why distinct provinces of animals and plants have not become more blended together — Brocchi's speculations on the loss of species — Stations of plants and animals — Causes on which they depend — Stations of plants, how affected by animals — Equilibrium in the number of species, how preserved — Peculiar efficacy of insects in this task — Rapidity with which certain insects multiply or decrease in numbers — Effect of omnivorous animals in preserving the equilibrium of species — Reciprocal influence of aquatic and terrestrial species on each other.

Theory of Linnæus. — It would be superfluous to examine the various attempts which were made to explain the phenomena of the distribution of species alluded to in the preceding chapters, in the infancy of the sciences of botany, zoology, and physical geography. The theories or rather conjectures then indulged now stand refuted by a simple statement of facts; and if Linnæus were living he would be the first to renounce the notions which he promulgated. For he imagined the habitable world to have been for a certain time limited to one small tract, the only portion of the earth's surface that was as yet laid bare by the subsidence of the primeval ocean. In this fertile spot he supposed the originals of all the species of plants

which exist on this globe to have been congregated, together with the first ancestors of all animals and of the human race. "In quâ commodè habitaverint animalia omnia, et vegetabilia lætè germinaverint." In order to accommodate the various habitudes of so many creatures, and to provide a diversity of climate suited to their several natures, the tract in which the creation took place was supposed to have been situated in some warm region of the earth, but to have contained a lofty mountain range, on the heights and in the declivities of which were to be found all temperatures and every climate, from that of the torrid to that of the frozen zone.*

That there never was a universal ocean since the planet was inhabited, or, rather, since the oldest groups of strata yet known to contain organic remains were formed, is proved by the presence of terrestrial plants in all the older formations; and if this conclusion was not established, yet no geologist could deny that, since the first small portion of the earth was laid dry, there have been many entire changes in the species of plants and animals inhabiting the land.

But, without dwelling on the above and other refuted theories, let us inquire whether some hypothesis cannot be substituted as simple as that of Linnæus, to which the phenomena now ascertained in regard to the distribution both of aquatic and terrestrial species may be referred. The following may, perhaps, be reconcilable with known facts: — Each species may have had its orgin in a single pair, or individual, where an individual was sufficient, and species may

* De terrâ habitabili incremento; also Prichard, Phys. Hist. of Mankind, vol. i. p. 17., where the hypotheses of different naturalists are enumerated.

have been created in succession at such times and in such places as to enable them to multiply and endure for an appointed period, and occupy an appointed space on the globe.

In order to explain this theory, let us suppose every living thing to be destroyed in the western hemisphere, both on the land and in the ocean, and permission to be given to man to people this great desert, by transporting into it animals and plants from the eastern hemisphere, a strict prohibition being enforced against introducing two original stocks of the same species.

Now it is easy to show that the result of such a mode of colonizing would correspond exactly, so far as regards the grouping of animals and plants, with that now observed throughout the globe. In the first place, it would be necessary for naturalists, before they imported species into particular localities, to study attentively the climate and other physical conditions of each spot. It would be no less requisite to introduce the different species in succession, so that each plant and animal might have time and opportunity to multiply before the species destined to prey upon it was admitted. Many herbs and shrubs, for example, must spread far and wide before the sheep, the deer, and the goat could be allowed to enter, lest they should devour and annihilate the original stocks of many plants, and then perish themselves for want of food. The above-mentioned herbivorous animals in their turn must be permitted to make considerable progress before the entrance of the first pair of wolves or lions. Insects must be allowed to swarm before the swallow could be permitted to skim through the air, and feast on thousands at one repast.

It is evident that, however equally in this case our

original stocks were distributed over the whole surface of land and water, there would nevertheless arise distinct botanical and zoological provinces, for there are a great many natural barriers which oppose common obstacles to the advance of a variety of species. Thus, for example, almost all the animals and plants naturalized by us, towards the extremity of South America, would be unable to spread beyond a certain limit, towards the east, west, and south; because they would be stopped by the ocean, and a few of them only would succeed in reaching the cooler latitudes of the northern hemisphere, because they would be incapable of bearing the heat of the tropics, through which they must pass. In the course of ages, undoubtedly, exceptions would arise, and some species might become common to the temperate and polar regions, or both sides of the equator; for I have before shown that the powers of diffusion conferred on some classes are very great. But we might confidently predict that these exceptions would never become so numerous as to invalidate the general rule.

Some of the plants and animals transplanted by us to the coast of Chili or Peru would never be able to cross the Andes, so as to reach the Eastern plains; nor, for a similar reason, would those first established in the Pampas, or the valleys of the Amazon and the Orinoco, ever arrive at the shores of the Pacific.

In the ocean an analogous state of things would prevail; for there, also, climate would exert a great influence in limiting the range of species, and the land would stop the migrations of aquatic tribes as effectually as the sea arrests the dispersion of the terrestrial. As certain birds, insects, and the seeds of plants can never cross the direction of prevailing winds, so cur-

rents form natural barriers to the dissemination of many oceanic races. A line of shoals may be as impassable to deep-water species, as are the Alps and the Andes to plants and animals peculiar to plains; while deep abysses may prove insuperable obstacles to the migrations of the inhabitants of shallow waters.

Supposed centres, or foci, of creation.—It is worthy of observation, that one effect of the introduction of single pairs of each species must be the confined range of certain groups in spots, which, like small islands, or solitary inland lakes, have few means of interchanging their inhabitants with adjoining regions. Now this congregating in a small space, of many peculiar species, would give an appearance of *centres* or *foci* of creation, as they have been termed, as if there were favourite points where the creative energy has been in greater action than in others, and where the numbers of peculiar organic beings have consequently become more considerable.

I do not mean to call in question the soundness of the inferences of some botanists, as to the former existence of certain limited spots whence species of plants have been propagated, radiating, as it were, in all directions from a common centre. On the contrary, I conceive these phenomena to be the necessary consequences of the plan of nature before suggested, operating during the successive mutations of the surface, some of which the geologist can prove to have taken place subsequently to the period when many species now existing were created. In order to exemplify how this arrangement of plants may have been produced, let us imagine that, about three centuries before the discovery of St. Helena (itself of submarine volcanic origin), a multitude of new islands had been

thrown up in the surrounding sea, and that these had each become clothed with plants emigrating from St. Helena, in the same manner as the wild plants of Campania have diffused themselves over Monte Nuovo. Whenever the first botanist investigated the new archipelago, he would, in all probability, find a different assemblage of plants in each of the islands of recent formation; but, in St. Helena itself, he would meet with individuals of every species belonging to all parts of the archipelago, and some, in addition, peculiar to itself, viz., those which had not been able to obtain a passage into any one of the surrounding new-formed lands. In this case, it might be truly said that the original island was the primitive focus, or centre, of a certain type of vegetation; whereas, in the surrounding islands, there would be a smaller number of species, yet all belonging to the same group.

But this peculiar distribution of plants would not warrant the conclusion that, in the space occupied by St. Helena, there had been a greater exertion of creative power than in the spaces of equal area occupied by the new adjacent lands, because, within the period in which St. Helena had acquired its peculiar vegetation, each of the spots supposed to be subsequently converted into land may have been the birth-places of a great number of *marine* animals and plants, which may have had time to scatter themselves far and wide over the southern Atlantic.

Why distinct provinces not more blended.—Perhaps it may be objected to some parts of the foregoing train of reasoning, that during the lapse of past ages, especially during many partial revolutions of the globe of comparatively modern date, different zoological and botanical provinces ought to have become more con-

founded and blended together — that the distribution of species approaches too nearly to what might have been expected, if animals and plants had been introduced into the globe when its physical geography had already assumed the features which it now wears; whereas we know that, in certain districts, considerable geographical changes have taken place since species identical with those now in being were created.

Brocchi's speculations on loss of species.— These, and many kindred topics cannot be fully discussed until we have considered, not merely the general laws which may regulate the first introduction of species, but those which may limit their *duration* on the earth. Brocchi, whose untimely death in Egypt is deplored by all who have the progress of geology at heart, has remarked, when hazarding some interesting conjectures respecting "the loss of species," that a modern naturalist had no small assurance, who declared "that individuals alone were capable of destruction, and that species were so perpetuated that nature could not annihilate them, so long as the planet lasted, or at least that nothing less than the shock of a comet, or some similar disaster, could put an end to their existence."* The Italian geologist, on the contrary, had satisfied himself, that many species of testacea, which formerly inhabited the Mediterranean, had become extinct, although a great number of others, which had been the contemporaries of those lost races, still survived. He came to the opinion, that about half the species which peopled the waters when the Subapennine strata were deposited had gone out of existence; and in this inference he does not appear to have been far wrong.

* Necker, Phytozool. Philosoph. p. 21. Brocchi, Conch. Foss. Subap. tome i. p. 229.

But, instead of seeking a solution of this problem, like some other geologists of his time, in a violent and general catastrophe, Brocchi endeavoured to imagine some regular and constant law by which species might be made to disappear from the earth gradually and in succession. The death, he suggested, of a species might depend, like that of individuals, on certain peculiarities of constitution conferred upon them at their birth; and as the longevity of the one depends on a certain force of vitality, which, after a period, grows weaker and weaker, so the duration of the other may be governed by the quantity of prolific power bestowed upon the species, which, after a season, may decline in energy, so that the fecundity and multiplication of individuals may be gradually lessened from century to century, "until that fatal term arrives when the embryo, incapable of extending and developing itself, abandons, almost at the instant of its formation, the slender principle of life by which it was scarcely animated, — and so all dies with it."

Now we might coincide in opinion with the Italian naturalist, as to the gradual extinction of species one after another, by the operation of regular and constant causes, without admitting an inherent principle of deterioration in their physiological attributes. We might concede, "that many species are on the decline, and that the day is not far distant when they will cease to exist;" yet deem it consistent with what we know of the nature of organic beings, to believe that the last individuals of each species retain their prolific powers in their full intensity.

Brocchi has himself speculated on the share which a change of climate may have had in rendering the Mediterranean unfit for the habitation of certain tes-

tacea, which still continued to thrive in the Indian Ocean, and of others which were now only represented by analogous forms within the tropics. He must also have been aware that other extrinsic causes, such as the progress of human population, or the increase of some one of the inferior animals, might gradually lead to the extirpation of a particular species, although its fecundity might remain to the last unimpaired. If, therefore, amid the vicissitudes of the animate and inanimate world, there are known causes capable of bringing about the decline and extirpation of species, it became him thoroughly to investigate the full extent to which these might operate, before he speculated on any cause of so purely hypothetical a kind as "the diminution of the prolific virtue."

If it could have been shown that some wild plant had insensibly dwindled away and died out, as sometimes happens to cultivated varieties propagated by cuttings, even though climate, soil, and every other circumstance should continue identically the same — if any animal had perished while the physical condition of the earth, and the number and force of its foes, with every other extrinsic cause, remained unaltered, then might we have some ground for suspecting that the infirmities of age creep on as naturally on species as upon individuals. But, in the absence of such observations, let us turn to another class of facts, and examine attentively the circumstances which determine the *stations* of particular animals and plants, and perhaps we shall discover, in the vicissitudes to which these stations are exposed, a cause fully adequate to explain the phenomena under consideration.

Stations of plants and animals.— Stations comprehend all the circumstances, whether relating to the

animate or inanimate world, which determine whether a given plant or animal can exist in a given place; so that if it be shown that stations can become essentially modified by the influence of known causes, it will follow that species, as well as individuals, are mortal.

Every naturalist is familiar with the fact, that although in a particular country, such as Great Britain, there may be more than three thousand species of plants, ten thousand insects, and a great variety in each of the other classes; yet there will not be more than a hundred, perhaps not half that number, inhabiting any given locality. There may be no want of space in the supposed tract: it may be a large mountain, or an extensive moor, or a great river-plain, containing room enough for individuals of every species in our island; yet the spot will be occupied by a few to the exclusion of many, and these few are enabled, throughout long periods, to maintain their ground successfully against every intruder, notwithstanding the facilities which species enjoy, by virtue of their power of diffusion, of invading adjacent territories.

The principal causes which enable a certain assemblage of plants thus to maintain their ground against all others depend, as is well known, on the relations between the physiological nature of each species, and the climate, exposure, soil, and other physical conditions of the locality. Some plants live only on rocks, others in meadows, a third class in marshes. Of the latter, some delight in a fresh-water morass,—others in salt marshes, where their roots may copiously absorb saline particles. Some prefer an alpine region in a warm latitude, where, during the heat of summer, they are constantly irrigated by the cool waters of melting snows. To others loose sand, so fatal to the

generality of species, affords the most proper station The *Carex arenaria* and the *Elymus arenarius* acquire their full vigour on a sandy dune, obtaining an ascendancy over the very plants which in a stiff clay would immediately stifle them.

Where the soil of a district is of so peculiar a nature that it is extremely favourable to certain species, and agrees ill with every other, the former get exclusive possession of the ground, and as in the case of heaths, live in societies. In like manner the Bog moss (*Sphagnum palustre*) is fully developed in peaty swamps, and becomes, like the heath, in the language of botanists, a social plant. Such monopolies, however, are not common, for they are checked by various causes. Not only are many species endowed with equal powers to obtain and keep possession of similar stations, but each plant, for reasons not fully explained by the physiologist, has the property of rendering the soil where it has grown less fitted for the support of other individuals of its own species, or even other species of the same family. Yet the same spot, so far from being impoverished, is improved, for plants of *another* family. Oaks, for example, render the soil more fertile for the fir tribe, and firs prepare the soil for oaks. Every agriculturist feels the force of this law of the organic world, and regulates accordingly the rotation of his crops.

Equilibrium in the number of species, how preserved. —" All the plants of a given country, says De Candolle, in his usual spirited style, " are at war one with another. The first which establish themselves by chance in a particular spot tend, by the mere occupancy of space, to exclude other species — the greater choke the smaller; the longest livers replace those

which last for a shorter period; the more prolific gradually make themselves masters of the ground, which species multiplying more slowly would otherwise fill."

In this continual strife it is not always the resources of the plant itself which enable it to maintain or extend its ground. Its success depends, in a great measure, on the number of its foes or allies, among the animals and plants inhabiting the same region. Thus, for example, an herb which loves the shade may multiply, if some tree with spreading boughs and dense foliage flourish in the neighbourhood. Another, which, if unassisted, would be overpowered by the rank growth of some hardy competitor, is secure because its leaves are unpalatable to cattle; which, on the other hand, annually crop down its antagonist, and rarely suffer it to ripen its seed.

Oftentimes we see some herb which has flowered in the midst of a thorny shrub, when all the other individuals of the same species, in the open fields around, are eaten down, and cannot bring their seed to maturity. In this case, the shrub has lent his armour of spines and prickles to protect the defenceless herb against the mouths of the cattle; and thus a few individuals which occupied, perhaps, the most unfavourable station in regard to exposure, soil, and other circumstances, may, nevertheless, by the aid of an ally, become the principal source whereby the winds are supplied with seeds which perpetuate the species throughout the surrounding tract. Thus, in the New Forest in Hampshire, the young oaks which are not consumed by the deer, or uprooted by the swine, are indebted to the holly for their escape.

In the above examples we see one plant shielding another from the attacks of animals; but instances

are, perhaps, still more numerous, where some animal defends a plant against the enmity of some other subject of the vegetable kingdom.

Scarcely any beast, observes a Swedish naturalist, will touch the nettle, but fifty different kinds of insects are fed by it.* Some of these seize upon the root, others upon the stem; some eat the leaves; others devour the seeds and flowers: but for this multitude of enemies, the nettle (*Urtica dioica*), which is now found in all the four quarters of the globe, would annihilate a great number of plants. Linnæus tells us, in his "Tour in Scania," that goats were turned into an island which abounded with the *Agrostis arundinacea*, where they perished by famine; but horses which followed them grew fat on the same plant. The goat, also, he says, thrives on the meadow-sweet, and water-hemlock, plants which are injurious to cattle.†

Agency of insects.—Every plant, observes Wilcke, has its proper insect allotted to it to curb its luxuriancy, and to prevent it from multiplying to the exclusion of others. "Thus grass in meadows sometimes flourishes so as to exclude all other plants: here the Phalæna graminis (*Bombyx gram.*), with her numerous progeny, find a well-spread table; they multiply in immense numbers, and the farmer, for some years, laments the failure of his crop; but, the grass being consumed, the moths die with hunger, or remove to another place. Now the quantity of grass being greatly diminished, the other plants, which were before choked by it, spring up, and the ground becomes variegated

* Amœn. Acad. vol. vi. p. 17. § 12.

† Ibid. vol. vii. p. 409.

with a multitude of different species of flowers. Had not Nature given a commission to this minister for that purpose, the grass would destroy a great number of species of vegetables, of which the equilibrium is now kept up." *

In the above passage allusion is made to the ravages committed in 1740, and the two following years, in many provinces in Sweden, by a most destructive insect. The same moth is said never to touch the fox-tail grass, so that it may be classed as a most active ally and benefactor of that species, and as peculiarly instrumental in preserving it in its present abundance.† A discovery of Rolander, cited in the treatise of Wilcke above mentioned, affords a good illustration of the checks and counter-checks which Nature has appointed to preserve the balance of power among species. "The *Phalæna strobilella* has the fir cone assigned to it to deposit its eggs upon; the young caterpillars coming out of the shell consume the cone and superfluous seed; but, lest the destruction should be too general, the *Ichneumon strobilellæ* lays its eggs in the caterpillar, inserting its long tail in the openings of the cone till it touches the included insect, for its body is too large to enter. Thus it fixes its minute egg upon the caterpillar, which being hatched destroys it." ‡

Entomologists enumerate many parallel cases where insects, appropriated to certain plants, are kept down by other insects, and these again by parasites expressly

* Amœn. Acad. vol. vi. p. 17. § 11, 12.

† Kirby and Spence, vol. i. p. 178.

‡ Amœn. Acad. vol. vi. § 14.

appointed to prey on them.* Few, perhaps, are in the habit of duly appreciating the extent to which insects are active in preserving the balance of species among plants, and thus regulating indirectly the relative numbers of many of the higher orders of terrestrial animals.

The peculiarity of their agency consists in their power of suddenly multiplying their numbers to a degree which could only be accomplished in a considerable lapse of time in any of the larger animals, and then as instantaneously relapsing, without the intervention of any violent disturbing cause, into their former insignificance.

If, for the sake of employing, on different but rare occasions, a power of many hundred horses, we were under the necessity of feeding all these animals at great cost in the intervals when their services were not required, we should greatly admire the invention of a machine, such as the steam-engine, which was capable at any moment of exerting the same degree of strength without any consumption of food during periods of inaction. The same kind of admiration is strongly excited when we contemplate the powers of insect life, in the creation of which the Author of Nature has been so prodigal. A scanty number of minute individuals, to be detected only by careful research, are ready in a few days, weeks, or months, to give birth to myriads, which may repress any degree of monopoly in another species, or remove nuisances, such as dead carcasses, which might taint the air. But no sooner has the destroying commission been executed than the gigantic power becomes dormant —

* Kirby and Spence, vol. iv. p. 218.

each of the mighty host soon reaches the term of its transient existence, and the season arrives when the whole species passes naturally into the egg, and thence into the larva and pupa state. In this defenceless condition it may be destroyed either by the elements, or by the augmentation of some of its numerous foes which may prey upon it in these stages of its transformation; or it often happens that in the following year the season proves unfavourable to the hatching of the eggs or the development of the pupæ.

Thus the swarming myriads depart which may have covered the vegetation like the aphides, or darkened the air like locusts. In almost every season there are some species which in this manner put forth their strength, and then, like Milton's spirits, which thronged the spacious hall, "reduce to smallest forms their shapes immense" —

> ———— So thick the aëry crowd
> Swarm'd and were straiten'd; till, the signal given,
> Behold a wonder! they but now who seem'd
> In bigness to surpass earth's giant sons,
> Now less than smallest dwarfs.

A few examples will illustrate the mode in which this force operates. It is well known that, among the countless species of the insect creation, some feed on animal, others on vegetable matter; and, upon considering a catalogue of eight thousand British insects and arachnidæ, Mr. Kirby found that these two divisions were nearly a counterpoise to each other, the carnivorous being somewhat preponderant. There are also distinct species, some appointed to consume living, others dead or putrid animal and vegetable substances. One female, of *Musca carnaria*, will give

birth to twenty thousand young; and the larvæ of many flesh-flies devour so much food in twenty-four hours, and grow so quickly, as to increase their weight two hundred-fold! In five days after being hatched they arrive at their full growth and size, so that there was ground, says Kirby, for the assertion of Linnæus, that three flies of *M. vomitoria* could devour a dead horse as quickly as a lion;* and another Swedish naturalist remarks, that so great are the powers of propagation of a single species even of the smallest insects, that each can commit, when required, more ravages than the elephant.†

Next to locusts, the aphides, perhaps, exert the greatest power over the vegetable world, and, like them, are sometimes so numerous as to darken the air. The multiplication of these little creatures is without parallel, and almost every plant has its peculiar species. Reaumur has proved that in five generations one aphis may be the progenitor of 5,904,900,000 descendants; and it is supposed that in one year there may be twenty generations.‡ Mr. Curtis observes that, as among caterpillars we find some that are constantly and unalterably attached to one or more particular species of plants, and others that feed indiscriminately on most sorts of herbage, so it is precisely with the aphides: some are particular, others more general, feeders; and as they resemble other insects in this respect, so they do also in being more abundant in some years than in others.§ In 1793 they were the chief, and in 1798 the sole, cause of the failure of the

* Kirby and Spence, vol. i. p. 250.

† Wilcke, Amœn. Acad. chap. ii.

‡ Kirby and Spence, vol. i. p. 174.

§ Trans. Linn. Soc. vol. vi.

hops. In 1794, a season almost unparalleled for drought, the hop was perfectly free from them; while peas and beans, especially the former, suffered very much from their depredations.

The ravages of the caterpillars of some of our smaller moths afford a good illustration of the temporary increase of a species. The oak-trees of a considerable wood have been stripped of their leaves as bare as in winter, by the caterpillars of a small green moth (*Tortrix viridana*), which has been observed the year following not to abound.* The silver Y moth (*Plusia gamma*), although one of our common species, is not dreaded by us for its devastations; but legions of their caterpillars have at times created alarm in France, as in 1735. Reaumur observes that the female moth lays about four hundred eggs; so that if twenty caterpillars were distributed in a garden, and all lived through the winter and became moths in the succeeding May, the eggs laid by these, if half of them were female and all fertile, would in the next generation produce 800,000 caterpillars.† A modern writer, therefore, justly observes that, did not Providence put causes in operation to keep them in due bounds, the caterpillars of this moth alone, leaving out of consideration the two thousand other British species, might soon destroy more than half of our vegetation.‡

In the latter part of the last century an ant most destructive to the sugar-cane (*Formica saccharivora*), appeared in such infinite hosts in the island of Grenada, as to put a stop to the cultivation of that vegetable. Their numbers were incredible. The plantations and

* Lib. Ent. Know., Insect Trans., p. 203. See Haworth, Lep.

† Reaumur, ii. 337.

‡ Lib. Ent. Know., Insect Trans., p. 212.

roads were filled with them; many domestic quadrupeds, together with rats, mice, and reptiles, and even birds, perished in consequence of this plague. It was not till 1780 that they were at length annihilated by torrents of rain, which accompanied a dreadful hurricane.*

Devastations caused by locusts.—We may conclude by mentioning some instances of the devastations of locusts in various countries. Among other parts of Africa, Cyrenaica has been at different periods infested by myriads of these creatures, which have consumed nearly every green thing. The effect of the havoc committed by them may be estimated by the famine they occasioned. St. Augustin mentions a plague of this kind in Africa which destroyed no less than 800,000 men in the kingdom of Masinissa alone, and many more upon the territories bordering upon the sea. It is also related, that in the year 591, an infinite army of locusts migrated from Africa into Italy; and, after grievously ravaging the country, were cast into the sea, when there arose a pestilence from their stench which carried off nearly a million of men and beasts.

In the Venetian territory, also, in 1478, more than thirty thousand persons are said to have perished in a famine occasioned by this scourge; and other instances are recorded of their devastations in France, Spain, Italy, Germany, &c. In different parts of Russia also, Hungary, and Poland,—in Arabia and India, and other countries,—their visitations have been periodically experienced. Although they have a preference for certain plants, yet, when these are consumed, they will

* Kirby and Spence, vol. i. p. 183. Castle, Phil. Trans., xxx. 346.

attack almost all the remainder. In the accounts of the invasions of locusts, the statements which appear most marvellous relate to the prodigious mass of matter which encumbers the sea wherever they are blown into it, and the pestilence arising from its putrefaction. Their dead bodies are said to have been, in some places, heaped one upon another, to the depth of four feet, in Russia, Poland, and Lithuania; and when, in southern Africa, they were driven into the sea by a north-west wind, they formed, says Barrow, along the shore, for fifty miles, a bank three or four feet high.* But when we consider that forests are stripped of their foliage, and the earth of its green garment, for thousands of square miles, it may well be supposed that the volume of animal matter produced may equal that of great herds of quadrupeds and flights of large birds suddenly precipitated into the sea.

The occurrence of such events at certain intervals, in hot countries, like the severe winters and damp summers returning after a series of years in a temperate zone, affect the proportional numbers of almost all classes of animals and plants, and are probably fatal to the existence of many which would otherwise thrive there; while, on the contrary, they must be favourable to certain species which, if deprived of such aid, might not maintain their ground.

Although it may usually be remarked that the extraordinary increase of some one species is immediately followed and checked by the multiplication of another, yet this does not always happen; partly because many species feed in common on the same kinds of food, and partly because many kinds of food are often consumed

* Travels in Africa, p. 257. Kirby and Spence, vol. i. p. 215.

indifferently by one and the same species. In the former case, where a variety of different animals have precisely the same taste, as, for example, when many insectivorous birds and reptiles devour alike some particular fly or beetle, the unusual numbers of these insects may cause only a slight and almost imperceptible augmentation of each of these species of bird and reptile. In the other instance, where one animal preys on others of almost every class, as, for example, where our English buzzards devour not only small quadrupeds, as rabbits and field-mice, but also birds, frogs, lizards, and insects, the profusion of any one of these last may cause all such general feeders to subsist more exclusively upon the species thus in excess, by which means the balance may be restored.

Agency of omnivorous animals.—The number of species which are nearly omnivorous is considerable; and although every animal has, perhaps, a predilection for some one description of food rather than another, yet some are not even confined to one of the great kingdoms of the organic world. Thus, when the racoon of the West Indies can procure neither fowls, fish, snails, nor insects, it will attack the sugar-canes, and devour various kinds of grain. The civets, when animal food is scarce, maintain themselves on fruits and roots.

Numerous birds, which feed indiscriminately on insects and plants, are perhaps more instrumental than any other of the terrestrial tribes in preserving a constant equilibrium between the relative numbers of different classes of animals and vegetables. If the insects become very numerous and devour the plants, these birds will immediately derive a larger portion of their subsistence from insects, just as the Arabians,

Syrians, and Hottentots feed on locusts, when the locusts devour their crops.

Reciprocal influence of aquatic and terrestrial species.—The intimate relation of the inhabitants of the water to those of the land, and the influence exerted by each on the relative number of species, must not be overlooked amongst the complicated causes which determine the existence of animals and plants in certain regions. A large portion of the amphibious quadrupeds and reptiles prey partly on aquatic plants and animals, and in part on terrestrial; and a deficiency of one kind of prey causes them to have immediate recourse to the other. The voracity of certain insects, as the dragon-fly, for example, is confined to the water during one stage of their transformations, and in their perfect state to the air. Innumerable water-birds, both of rivers and seas, derive in like manner their food indifferently from either element; so that the abundance or scarcity of prey in one induces them either to forsake or more constantly to haunt the other. Thus an intimate connexion between the state of the animate creation in a lake or river, and in the adjoining dry land, is maintained; or between a continent, with its lakes and rivers, and the ocean. It is well known that many birds migrate, during stormy seasons, from the sea-shore into the interior, in search of food; while others, on the contrary, urged by like wants, forsake their inland haunts, and live on substances rejected by the tide.

The migration of fish into rivers during the spawning season, supplies another link of the same kind. Suppose the salmon to be reduced in numbers by some marine foes, as by seals and grampuses, the consequence must often be, that in the course of a few years

the otters at the distance of several hundred miles inland, will be lessened in number from the scarcity of fish. On the other hand, if there be a dearth of food for the young fry of the salmon in rivers and estuaries, so that few return to the sea, the sand-eels and other marine species, which are usually kept down by the salmon, will swarm in greater profusion.

It is unnecessary to accumulate a greater number of illustrations in order to prove that the stations of different plants and animals depend on a great complication of circumstances,— on an immense variety of relations in the state of the animate and inanimate worlds. Every plant requires a certain climate, soil, and other conditions, and often the aid of many animals, in order to maintain its ground. Many animals feed on certain plants, being often restricted to a small number, and sometimes to one only; other members of the animal kingdom feed on plant-eating species, and thus become dependent on the conditions of the *stations* not only of their prey, but of the plants consumed by them.

Having duly reflected on the nature and extent of these mutual relations in the different parts of the organic and inorganic worlds, we may next proceed to examine the results which may be anticipated from the fluctuations now continually in progress in the state of the earth's surface, and in the geographical distribution of its living productions.

CHAPTER IX.

EXTINCTION OF SPECIES. — CHANGES IN THE STATIONS OF ANIMALS.

Extension of the range of one species alters the condition of many others — The first appearance of a new species causes the chief disturbance — Changes known to have resulted from the advance of human population — Whether man increases the productive powers of the earth — Indigenous quadrupeds and birds extirpated in Great Britain — Extinction of the dodo — Rapid propagation of domestic quadrupeds in America — Power of exterminating species no prerogative of man — Concluding remarks.

We have seen that the stations of animals and plants depend not merely on the influence of external agents in the inanimate world, and the relations of that influence to the structure and habits of each species, but also on the state of the contemporary living beings which inhabit the same part of the globe. In other words, the possibility of the existence of a certain species in a given place, or of its thriving more or less therein, is determined not merely by temperature, humidity, soil, elevation, and other circumstances of the like kind; but also by the existence or non-existence, the abundance or scarcity, of a particular assemblage of other plants and animals in the same region.

If it be shown that both these classes of circumstances, whether relating to the animate or inanimate creation, are perpetually changing, it will follow that species are subject to incessant vicissitudes; and if the

result of these mutations, in the course of ages, be so great as materially to affect the general condition of *stations*, it will follow that the successive destruction of species must now be part of the regular and constant order of nature.

Extension of the range of one species alters the condition of others. — It will be desirable, first, to consider the effects which every extension of the numbers or geographical range of one species must produce on the condition of others inhabiting the same regions. When the necessary consequences of such extensions have been fully explained, the reader will be prepared to appreciate the important influence which slight modifications in the physical geography of the globe may exert on the condition of organic beings.

In the first place, it is clear that when any region is stocked with as great a variety of animals and plants as the productive powers of that region will enable it to support, the addition of any new species, or the *permanent* numerical increase of one previously established, must always be attended either by the local extermination or the numerical decrease of some other species.

There may undoubtedly be considerable fluctuations from year to year, and the equilibrium may be again restored without any permanent alteration; for, in particular seasons, a greater supply of heat, humidity, or other causes, may augment the total quantity of vegetable produce, in which case all the animals subsisting on vegetable food, and others which prey on them, may multiply without any one species giving way: but whilst the aggregate quantity of vegetable produce remains unaltered, the progressive increase of one animal or plant implies the decline of another.

All agriculturists and gardeners are familiar with the fact that, when weeds intrude themselves into the space appropriated to cultivated species, the latter are starved in their growth or stifled. If we abandon for a short time a field or garden, a host of indigenous plants,

The darnel, hemlock, and rank fumitory,

pour in and obtain the mastery, extirpating the exotics, or putting an end to the monopoly of some native plants.

If we enclose a park, and stock it with as many deer as the herbage will support, we cannot add sheep without lessening the number of the deer; nor can other herbivorous species be subsequently introduced, unless the individuals of each species in the park become fewer in proportion.

So, if there be an island where leopards are the only beasts of prey, and the lion, tiger, and hyæna afterwards enter, the leopards, if they stand their ground, will be reduced in number. If the locusts then arrive and swarm greatly, this may deprive a large number of plant-eating animals of their food, and thereby cause a famine, not only among them, but among the beasts of prey: certain species, perhaps, which had the weakest footing in the island may thus be annihilated.

We have seen how many distinct geographical provinces there are of aquatic and terrestrial species, and how great are the powers of migration conferred on different classes, whereby the inhabitants of one region may be enabled from time to time to invade another, and do actually so migrate and diffuse themselves over new countries. Now, although our knowledge of the history of the animate creation dates from so recent a

period, that we can scarcely trace the advance or decline of any animal or plant, except in those cases where the influence of man has intervened; yet we can easily conceive what must happen when some new colony of wild animals or plants enters a region for the first time, and succeeds in establishing itself.

Supposed effects of the first entrance of the polar bear into Iceland.—Let us consider how great are the devastations committed at certain periods by the Greenland bears, when they are drifted to the shores of Iceland in considerable numbers on the ice. These periodical invasions are formidable even to man; so that when the bears arrive, the inhabitants collect together, and go in pursuit of them with fire-arms—each native who slays one being rewarded by the king of Denmark. The Danes of old, when they landed in their marauding expeditions upon our coast, hardly excited more alarm; nor did our islanders muster more promptly for the defence of their lives and property against a common enemy, than the modern Icelanders against these formidable brutes. It often happens, says Henderson, that the natives are pursued by the bear when he has been long at sea, and when his natural ferocity has been heightened by the keenness of hunger; if unarmed, it is frequently by stratagem only that they make their escape.*

Let us cast our thoughts back to the period when the first polar bears reached Iceland, before it was colonized by the Norwegians in 874; we may imagine the breaking up of an immense barrier of ice, like that which, in 1816 and the following year, disappeared from the east coast of Greenland, which it had sur-

* Journal of a residence in Iceland, p. 276.

rounded for four centuries. By the aid of such means of transportation a great number of these quadrupeds might effect a landing at the same time, and the havoc which they would make among the species previously settled in the island would be terrific. The deer, foxes, seals, and even birds, on which these animals sometimes prey, would be soon thinned down.

But this would be a part only, and probably an insignificant portion, of the aggregate amount of change brought about by the new invader. The plants on which the deer fed being less consumed in consequence of the lessened numbers of that herbivorous species, would soon supply more food to several insects, and probably to some terrestrial testacea, so that the latter would gain ground. The increase of these would furnish other insects and birds with food, so that the numbers of these last would be augmented. The diminution of the seals would afford a respite to some fish which they had persecuted; and these fish, in their turn, would then multiply and press upon their peculiar prey. Many water-fowls, the eggs and young of which are devoured by foxes, would increase when the foxes were thinned down by the bears; and the fish on which the water-fowls subsisted would then, in their turn, be less numerous. Thus the numerical proportions of a great number of the inhabitants, both of the land and sea, might be permanently altered by the settling of one new species in the region; and the changes caused indirectly would ramify through all classes of the living creation, and be almost endless.

An actual illustration of what we have here only proposed hypothetically, is in some degree afforded by the selection of small islands by the eider duck for its residence during the season of incubation, its nests

being seldom if ever found on the shores of the main-land, or even of a large island. The Icelanders are so well aware of this, that they have expended a great deal of labour in forming artificial islands, by separating from the main-land certain promontories, joined to it by narrow isthmuses. This insular position is necessary to guard against the destruction of the eggs and young birds, by foxes, dogs, and other animals. One year, says Hooker, it happened that, in the small island of Vidoe, adjoining the coast of Iceland, a fox got over *upon the ice*, and caused great alarm, as an immense number of ducks were then sitting on their eggs or young ones. It was long before he was taken, which was at last, however, effected by bringing another fox to the island, and fastening it by a string near the haunt of the former, by which he was allured within shot of the hunter.*

The first appearance of a new species causes the chief disturbance.—It is usually the first appearance of an animal or plant, in a region to which it was previously a stranger, that gives rise to the chief alteration; since, after a time, an equilibrium is again established. But it must require ages before such a new adjustment of the relative forces of so many conflicting agents can be definitely settled. The causes in simultaneous action are so numerous, that they admit of an almost infinite number of combinations; and it is necessary that all these should have occurred once before the total amount of change, capable of flowing from any new disturbing force, can be estimated.

Thus, for example, suppose that once in two cen-

* Tour in Iceland, vol. i. p. 64, second edition.

turies a frost of unusual intensity, or a volcanic eruption of great violence accompanied by floods from the melting of glaciers, should occur in Iceland; or an epidemic disease, fatal to the larger number of individuals of some one species, and not affecting others, — these, and a variety of other contingencies, all of which may occur at once, or at periods separated by different intervals of time, ought to happen before it would be possible for us to declare what ultimate alteration the presence of any new comer, such as the bear before mentioned, might occasion in the animal population of the isle.

Every new condition in the state of the organic or inorganic creation, a new animal or plant, an additional snow-clad mountain, any permanent change, however slight in comparison to the whole, gives rise to a new order of things, and may make a material change in regard to some one or more species. Yet a swarm of locusts, or a frost of extreme intensity, or an epidemic disease, may pass away without any great apparent derangement; no species may be lost, and all may soon recover their former relative numbers, because the same scourges may have visited the region again and again, at preceding periods. Every plant that was incapable of resisting such a degree of cold, every animal which was exposed to be entirely cut off by an epidemic or by famine, caused by the consumption of vegetation by the locusts, may have perished already, so that the subsequent recurrence of similar catastrophes is attended only by a temporary change.

Changes caused by Man.

We are best acquainted with the mutations brought about by the progress of human population, and the

growth of plants and animals favoured by man. To these, therefore, we should in the first instance turn our attention. If we conclude, from the concurrent testimony of history and of the evidence yielded by geological data, that man is, comparatively speaking, of very modern origin, we must at once perceive how great a revolution in the state of the animate world the increase of the human race, considered merely as consumers of a certain quantity of organic matter, must necessarily cause.

Whether man increases the productive powers of the earth.—It may, perhaps, be said, that man has, in some degree, compensated for the appropriation to himself of so much food, by artificially improving the natural productiveness of soils, by irrigation, manure, and a judicious intermixture of mineral ingredients conveyed from different localities. But it admits of reasonable doubt whether, upon the whole, we fertilize or impoverish the lands which we occupy. This assertion may seem startling to many; because they are so much in the habit of regarding the sterility or productiveness of land in relation to the wants of man, and not as regards the organic world generally. It is difficult, at first, to conceive, if a morass is converted into arable land, and made to yield a crop of grain, even of moderate abundance, that we have not improved the capabilities of the habitable surface—that we have not empowered it to support a larger quantity of organic life. In such cases, however, a tract, before of no utility to man, may be reclaimed, and become of high agricultural importance, though it may, nevertheless, yield a scantier vegetation. If a lake be drained, and turned into a meadow, the space will provide sustenance to man, and many terrestrial animals service-

able to him, but not, perhaps, so much food as it previously yielded to the aquatic races.

If the pestiferous Pontine Marshes were drained, and covered with corn, like the plains of the Po, they might, perhaps, feed a smaller number of animals than they do now; for these morasses are filled with herds of buffaloes and swine, and they swarm with birds, reptiles, and insects.

The felling of dense and lofty forests, which covered, even within the records of history, a considerable space on the globe, now tenanted by civilized man, must generally have lessened the amount of vegetable food throughout the space where these woods grew. We must also take into our account the area covered by towns, and a still larger surface occupied by roads.

If we force the soil to bear extraordinary crops one year, we are, perhaps, compelled to let it lie fallow the next. But nothing so much counterbalances the fertilizing effects of human art as the extensive cultivation of foreign herbs and shrubs, which, although they are often more nutritious to man, seldom thrive with the same rank luxuriance as the native plants of a district. Man is, in truth, continually striving to diminish the natural diversity of the *stations* of animals and plants in every country, and to reduce them all to a small number fitted for species of economical use. He may succeed perfectly in attaining his object, even though the vegetation be comparatively meagre, and the total amount of animal life be greatly lessened.

Spix and Martius have given a lively description of the incredible number of insects which lay waste the crops in Brazil, besides swarms of monkeys, flocks of parrots, and other birds, as well as the paca, agouti,

and wild swine. They describe the torment which the planter and the naturalist suffer from the musquitoes, and the devastation of the ants and blattæ ; they speak of the dangers to which they were exposed from the jaguar, the poisonous serpents, crocodiles, scorpions, centipedes, and spiders. But with the increasing population and cultivation of the country, say these naturalists, these evils will gradually diminish; when the inhabitants have cut down the woods, drained the marshes, made roads in all directions, and founded villages and towns, man will, by degrees, triumph over the rank vegetation and the noxious animals, and all the elements will second and amply recompense his activity.*

The number of human beings now peopling the earth is supposed to amount to eight hundred millions, so that we may easily understand how great a number of beasts of prey, birds, and animals of every class, this prodigious population must have displaced, independently of the still more important consequences which have followed from the derangement brought about by man in the relative numerical strength of particular species.

Indigenous quadrupeds and birds extirpated in Great Britain. — Let us make some inquiries into the extent of the influence which the progress of society has exerted during the last seven or eight centuries, in altering the distribution of indigenous British animals. Dr. Fleming has prosecuted this inquiry with his usual zeal and ability; and in a memoir on the subject has enumerated the best authenticated examples of the decrease or extirpation of certain species during a

* Travels in Brazil, vol. i. p. 260.

period when our population has made the most rapid advances. I shall offer a brief outline of his results.*

The stag, as well as the fallow deer and the roe, were formerly so abundant in our island, that according to Lesley, from five hundred to a thousand were sometimes slain at a hunting-match; but the native races would already have been extinguished, had they not been carefully preserved in certain forests. The otter, the marten, and the polecat, were also in sufficient numbers to be pursued for the sake of their fur; but they have now been reduced within very narrow bounds. The wild cat and fox have also been sacrificed throughout the greater part of the country, for the security of the poultry-yard or the fold. Badgers have been expelled from nearly every district, which at former periods they inhabited.

Besides these, which have been driven out from some haunts, and every where reduced in number, there are some which have been wholly extirpated; such as the ancient breed of indigenous horses, and the wild boar; of the wild oxen, a few remains are still preserved in the parks of some of our nobility. The beaver, which was eagerly sought after for its fur, had become scarce at the close of the ninth century; and, by the twelfth century, was only to be met with, according to Giraldus de Barri, in one river in Wales, and another in Scotland. The wolf, once so much dreaded by our ancestors, is said to have maintained its ground in Ireland so late as the beginning of the eighteenth century (1710), though it had been extirpated in Scotland thirty years before, and in England at a much earlier period. The bear, which, in Wales,

* Ed. Phil. Journ. No. xxii. p. 287. Oct. 1824.

was regarded as a beast of the chase equal to the hare or the boar,* only perished, as a native of Scotland, in the year 1057.†

Many native birds of prey have also been the subjects of unremitting persecution. The eagles, larger hawks, and ravens, have disappeared from the more cultivated districts. The haunts of the mallard, the snipe, the redshank, and the bittern, have been drained equally with the summer dwellings of the lapwing and the curlew. But these species still linger in some portion of the British isles; whereas the larger capercailzies, or wood grouse, formerly natives of the pine-forests of Ireland and Scotland, have been destroyed within the last sixty years. The egret and the crane, which appear to have been formerly very common in Scotland, are now only occasional visitants.‡

The bustard (*Otis tarda*), observes Graves, in his British Ornithology,§ "was formerly seen in the downs and heaths of various parts of our island, in flocks of forty or fifty birds; whereas it is now a circumstance of rare occurrence to meet with a single individual." Bewick also remarks, "that they were formerly more common in this island than at present; they are now found only in the open counties of the south and east —in the plains of Wiltshire, Dorsetshire, and some parts of Yorkshire."|| In the few years that have elapsed since Bewick wrote, this bird has entirely disappeared from Wiltshire and Dorsetshire.

These changes, it may be observed, are derived from very imperfect memorials, and relate only to the

* Ray. Syn. Quad. p. 214.

† Fleming, Ed. Phil. Journ. No. xxii. p. 295.

‡ Fleming, ibid. p. 292.

§ Vol. iii. London, 1821.

|| Land Birds, vol. i. p. 316. ed. 1821.

larger and more conspicuous animals inhabiting a small spot on the globe; but they cannot fail to exalt our conception of the enormous revolutions which, in the course of several thousand years, the whole human species must have effected.

Extinction of the Dodo.—The kangaroo and the emu are retreating rapidly before the progress of colonization in Australia; and it scarcely admits of doubt, that the general cultivation of that country must lead to the extirpation of both. The most striking example of the loss, even within the last two centuries, of a remarkable species, is that of the dodo — a bird first seen by the Dutch, when they landed on the Isle of France, at that time uninhabited, immediately after the discovery of the passage to the East Indies by the Cape of Good Hope. It was of a large size, and singular form; its wings short, like those of an ostrich, and wholly incapable of sustaining its heavy body, even for a short flight. In its general appearance it differed from the ostrich, cassowary, or any known bird.

Many naturalists gave figures of the dodo after the commencement of the seventeenth century; and there is a painting of it in the British Museum, which is said to have been taken from a living individual. Beneath the painting is a leg, in a fine state of preservation, which ornithologists are agreed cannot belong to any other known bird. In the museum at Oxford, also, there is a foot and a head, in an imperfect state; but M. Cuvier doubts the identity of this species with that of which the painting is preserved in London.

In spite of the most active search, during the last century, no information respecting the dodo was obtained, and some authors have gone so far as to pre-

tend that it never existed; but, amongst a great mass of satisfactory evidence in favour of the recent existence of this species, we may mention that an assemblage of fossil bones was recently discovered under a bed of lava, in the Isle of France, and sent to the Paris Museum, by M. Desjardins. They almost all belonged to a large living species of land-tortoise, called *Testudo Indica;* but amongst them were the head, sternum, and humerus of the dodo. M. Cuvier showed me these valuable remains in Paris, and assured me that they left no doubt in his mind that the huge bird was one of the gallinaceous tribe.*

Rapid propagation of domestic quadrupeds over the American continent.—Next to the direct agency of man, his indirect influence in multiplying the numbers of large herbivorous quadrupeds of domesticated races may be regarded as one of the most obvious causes of the extermination of species. On this, and on several other grounds, the introduction of the horse, ox, and other mammalia, into America, and their rapid propagation over that continent within the last three centuries, is a fact of great importance in natural history. The extraordinary herds of wild cattle and horses which overran the plains of South America sprung from a very few pairs first carried over by the Spaniards; and they prove that the wide geographical range of large species in great continents does not necessarily imply that they have existed there from remote periods.

Humboldt observes, in his Travels, on the authority of Azzara, that it is believed there exist, in the Pampas

* Sur quelques Ossemens, &c.—Ann. des Sci. tome xxi. p. 103. Sept. 1830.

of Buenos Ayres, twelve million cows and three million horses, without comprising, in this enumeration, the cattle that have no acknowledged proprietor. In the Llanos of Caraccas, the rich hateros, or proprietors of pastoral farms, are entirely ignorant of the number of cattle they possess. The young are branded with a mark peculiar to each herd, and some of the most wealthy owners mark as many as fourteen thousand a year.* In the northern plains, from the Orinoco to the lake of Maracaybo, M. Depons reckoned that 1,200,000 oxen, 180,000 horses, and 90,000 mules, wandered at large.† In some parts of the valley of the Mississippi, especially in the country of the Osage Indians, wild horses are immensely numerous.

The establishment of black cattle in America dates from Columbus's second voyage to St. Domingo. They there multiplied rapidly; and that island presently became a kind of nursery from which these animals were successively transported to various parts of the continental coast, and from thence into the interior. Notwithstanding these numerous exportations, in twenty-seven years after the discovery of the island, herds of four thousand head, as we learn from Oviedo, were not uncommon, and there were even some that amounted to eight thousand. In 1587, the number of hides exported from St. Domingo alone, according to Acosta's report, was 35,444; and in the same year there were exported 64,350 from the ports of New Spain. This was in the sixty-fifth year after the taking of Mexico, previous to which event the Spaniards, who came into that country, had not been able to engage in any thing else than war.‡

* Pers. Nar. vol. iv.

† Quarterly Review, vol. xxi. p. 335.

‡ Ibid.

Every one is aware that these animals are now established throughout the American continent, from Canada to the Straits of Magellan.

The ass has thriven very generally in the New World; and we learn from Ulloa, that in Quito they ran wild, and multiplied in amazing numbers, so as to become a nuisance. They grazed together in herds, and when attacked defended themselves with their mouths. If a horse happened to stray into the places where they fed, they all fell upon him, and did not cease biting and kicking till they left him dead.*

The first hogs were carried to America by Columbus, and established in the island of St. Domingo the year following its discovery, in November, 1493. In succeeding years they were introduced into other places where the Spaniards settled; and, in the space of half a century, they were found established in the New World, from the latitude of 25° north, to the 40th degree of south latitude. Sheep, also, and goats have multiplied enormously in the New World, as have also the cat and the rat; which last, as before stated, has been imported unintentionally in ships. The dogs introduced by man which have at different periods become wild in America, hunted in packs, like the wolf and the jackal, destroying not only hogs, but the calves and foals of the wild cattle and horses.

Ulloa in his Voyage, and Buffon on the authority of old writers, relate a fact which illustrates very clearly the principle before explained, of the check which the increase of one animal necessarily offers to that of another. The Spaniards had introduced goats into the island of Juan Fernandez, where they became so

* Ulloa's Voyage. Wood's Zoog., vol. i. p. 9.

prolific as to furnish the pirates who infested those seas with provisions. In order to cut off this resource from the buccaneers, a number of dogs were turned loose into the island; and so numerous did they become in their turn, that they destroyed the goats in every accessible part, after which the number of the wild dogs again decreased.*

Increase of rein-deer imported into Iceland.—As an example of the rapidity with which a large tract may become peopled by the offspring of a single pair of quadrupeds, it may be mentioned that in the year 1773 thirteen rein-deer were exported from Norway, only three of which reached Iceland. These were turned loose into the mountains of Guldbringè Syssel, where they multiplied so greatly, in the course of forty years, that it was not uncommon to meet with herds, consisting of from forty to one hundred, in various districts.

The rein-deer, observes a modern writer, is in Lapland a loser by his connexion with man, but Iceland will be this creature's paradise. There is, in the interior, a tract which Sir G. Mackenzie computes at not less than forty thousand square miles, without a single human habitation, and almost entirely unknown to the natives themselves. There are no wolves; the Icelanders will keep out the bears; and the rein-deer, being almost unmolested by man, will have no enemy whatever, unless it has brought with it its own tormenting gadfly.†

Besides the quadrupeds before enumerated, our domestic fowls have also succeeded in the West Indies and America, where they have the common fowl, the

* Buffon, vol. v. p. 100. Ulloa's Voyage, vol. ii. p. 220.

† Travels in Iceland in 1810, p. 342.

goose, the duck, the peacock, the pigeon, and the guinea-fowl. As these were often taken suddenly from the temperate to very hot regions, they were not reared at first without much difficulty; but after a few generations, they became familiarized to the climate, which, in many cases, approached much nearer than that of Europe to the temperature of their original native countries.

The fact of so many millions of wild and tame individuals of our domestic species, almost all of them the largest quadrupeds and birds, having been propagated throughout the new continent within the short period that has elapsed since the discovery of America, while no appreciable improvement can have been made in the productive powers of that vast continent, affords abundant evidence of the extraordinary changes which accompany the diffusion and progressive advancement of the human race over the globe. That it should have remained for us to witness such mighty revolutions is a proof, even if there was no other evidence, that the entrance of man into the planet is, comparatively speaking, of extremely modern date, and that the effects of his agency are only beginning to be felt.

Population which the globe is capable of supporting. — A modern writer has estimated, that there are in America upwards of four million square miles of useful soil, each capable of supporting 200 persons; and nearly six million, each mile capable of supporting 490 persons.* If this conjecture be true, it will follow, as that author observes, that if the natural resources of America were fully developed, it would afford sustenance to five times as great a number of inhabitants

* Maclaren, art. America, Encyc. Britannica.

as the entire mass of human beings existing at present upon the globe. The new continent, he thinks, though less than half the size of the old, contains an equal quantity of useful soil, and much more than an equal amount of productive power. Be this as it may, we may safely conclude that the amount of human population now existing constitutes but a small proportion of that which the globe is capable of supporting, or which it is destined to sustain at no distant period, by the rapid progress of society, especially in America, Australia, and certain parts of the old continent.

Power of exterminating species no prerogative of man. — But if we reflect that many millions of square miles of the most fertile land, occupied originally by a boundless variety of animal and vegetable forms, have been already brought under the dominion of man, and compelled, in a great measure, to yield nourishment to him, and to a limited number of plants and animals which he has caused to increase, we must at once be convinced, that the annihilation of a multitude of species has already been effected, and will continue to go on hereafter, in certain regions, in a still more rapid ratio, as the colonies of highly civilized nations spread themselves over unoccupied lands.

Yet, if we wield the sword of extermination as we advance, we have no reason to repine at the havoc committed, nor to fancy, with the Scottish poet, that "we violate the social union of nature;" or complain, with the melancholy Jaques, that we

> Are mere usurpers, tyrants, and what's worse,
> To fright the animals and to kill them up
> In their assign'd and native dwelling-place.

We have only to reflect, that in thus obtaining possession of the earth by conquest, and defending our

acquisitions by force, we exercise no exclusive prerogative. Every species which has spread itself from a small point over a wide area must, in like manner, have marked its progress by the diminution or the entire extirpation of some other, and must maintain its ground by a successful struggle against the encroachments of other plants and animals. That minute parasitic plant, called "the rust" in wheat, has, like the Hessian fly, the locust, and the aphis, caused famines ere now amongst the "lords of the creation." The most insignificant and diminutive species, whether in the animal or vegetable kingdom, have each slaughtered their thousands, as they disseminated themselves over the globe, as well as the lion, when first it spread itself over the tropical regions of Africa.

Concluding remarks.— Although we have as yet considered one class only of the causes (the organic) by which species may become exterminated, yet it cannot but appear evident that the continued action of these alone, throughout myriads of future ages, must work an entire change in the state of the organic creation, not merely on the continents and islands, where the power of man is chiefly exerted, but in the great ocean, where his control is almost unknown. The mind is prepared by the contemplation of such future revolutions to look for the signs of others, of an analogous nature, in the monuments of the past. Instead of being astonished at the proofs there manifested of endless mutations in the animate world, they will appear to one who has thought profoundly on the fluctuations now in progress, to afford evidence in favour of the uniformity of the system, unless, indeed, we are precluded from speaking of *uniformity* when we characterize a principle of endless variation.

CHAPTER X.

EXTINCTION OF SPECIES. — INFLUENCE OF INORGANIC CAUSES.

Powers of diffusion indispensable, that each species may maintain its ground — How changes in physical geography affect the distribution of species — Rate of the change of species due to this cause cannot be uniform — Every change in the physical geography of large regions tends to the extinction of species — Effects of a general alteration of climate on the migration of species — Gradual refrigeration would cause species in the northern and southern hemispheres to become distinct — elevation of temperature the reverse — Effects on the condition of species which must result from inorganic changes inconsistent with the theory of transmutation.

Powers of diffusion indispensable, that each species may maintain its ground. — HAVING shown in the last chapter how considerably the numerical increase or the extension of the geographical range of any one species must derange the numbers and distribution of others, let us now direct our attention to the influence which the inorganic causes described in the second book are continually exerting on the habitations of species.

So great is the instability of the earth's surface, that if nature were not continually engaged in the task of sowing seeds and colonizing animals, the depopulation of a certain portion of the habitable sea and land would

in a few years be considerable. Whenever a river transports sediment into a lake or sea, so as materially to diminish its depth, the aquatic animals and plants which delight in deep water are expelled: the tract, however, is not allowed to remain useless; but is soon peopled by species which require more light and heat, and thrive where the water is shallow. Every addition made to the land by the encroachment of the delta of a river, banishes many subaqueous species from their native abodes; but the new-formed plain is not permitted to lie unoccupied, being instantly covered with terrestrial vegetation. The ocean devours continuous lines of sea-coast, and precipitates forests or rich pasture land into the waves: but this space is not lost to the animate creation; for shells and sea-weed soon adhere to the new-made cliffs, and numerous fish people the channel which the current has scooped out for itself. No sooner has a volcanic island been thrown up than some lichens begin to grow upon it, and it is sometimes clothed with verdure while smoke and ashes are still occasionally thrown from the crater. The cocoa, pandanus, and mangrove take root upon the coral reef before it has fairly risen above the waves. The burning stream of lava that descends from Etna rolls through the stately forest, and converts to ashes every tree and herb which stands in its way; but the black strip of land thus desolated is covered again, in the course of time, with oaks, pines, and chestnuts, as luxuriant as those which the fiery torrent swept away.

Every flood and landslip, every wave which a hurricane or earthquake throws upon the shore, every shower of volcanic dust and ashes which buries a country far and wide to the depth of many feet, every

advance of the sand-flood, every conversion of salt-water into fresh, when rivers alter their main channel of discharge, every permanent variation in the rise or fall of tides in an estuary — these and countless other causes displace, in the course of a few centuries, certain plants and animals from stations which they previously occupied. If, therefore, the Author of nature had not been prodigal of those numerous contrivances, before alluded to, for spreading all classes of organic beings over the earth — if he had not ordained that the fluctuations of the animate and inanimate creation should be in perfect harmony with each other, it is evident that considerable spaces, now the most habitable on the globe, would soon be as devoid of life as are the Alpine snows, or the dark abysses of the ocean, or the moving sands of the Sahara.

The powers, then, of migration and diffusion conferred on animals and plants are indispensable to enable them to maintain their ground, and would be necessary, even though it were never intended that a species should gradually extend its geographical range. But a facility of shifting their quarters being once given, it cannot fail to happen that the inhabitants of one province should occasionally penetrate into some other; since the strongest of those barriers which I before described as separating distinct regions are all liable to be thrown down, one after the other, during the vicissitudes of the earth's surface.

How changes in physical geography affect the distribution of species. — The numbers and distribution of particular species are affected in two ways, by changes in the physical geography of the earth: — First, these changes promote or retard the migrations of species; secondly, they alter the physical conditions of the

localities which species inhabit. If the ocean should gradually wear its way through an isthmus, like that of Suez, it would open a passage for the intermixture of the aquatic tribes of two seas previously disjoined, and would, at the same time, close a free communication which the terrestrial plants and animals of two continents had before enjoyed. These would be, perhaps, the most important consequences, in regard to the distribution of species, which would result from the breach made by the sea in such a spot; but there would be others of a distinct nature, such as the conversion of a certain tract of land, which formed the isthmus, into sea. This space, previously occupied by terrestrial plants and animals, would be immediately delivered over to the aquatic; a local revolution which might have happened in innumerable other parts of the globe, without being attended by any alteration in the blending together of species of two distinct provinces.

Rate of change of species cannot be uniform. — This observation leads me to point out one of the most interesting conclusions to which we are led by the contemplation of the vicissitudes of the inanimate world in relation to those of the animate. It is clear that, if the agency of inorganic causes be uniform, as I have supposed, they must operate very irregularly on the state of organic beings, so that the rate according to which these will change in particular regions will not be equal in equal periods of time.

I am not about to advocate the doctrine of general catastrophes recurring at certain intervals, as in the ancient Oriental cosmogonies, nor do I doubt that, if very considerable periods of equal duration could be compared one with another, the rate of change in the

living, as well as in the inorganic world, might be nearly uniform; but if we regard each of the causes separately, which we know to be at present the most instrumental in remodelling the state of the surface, we shall find that we must expect each to be in action for thousands of years, without producing any extensive alterations in the habitable surface, and then to give rise, during a very brief period, to important revolutions.

Illustration derived from subsidences. — I shall illustrate this principle by a few of the most remarkable examples which present themselves. In the course of the last century, as we have seen, a considerable number of instances are recorded of the solid surface, whether covered by water or not, having been permanently sunk or upraised by subterranean movements. Most of these convulsions are only accompanied by temporary fluctuations in the state of limited districts, and a continued repetition of these events for thousands of years might not produce any decided change in the state of many of those great zoological or botanical provinces of which I have sketched the boundaries.

When, for example, large parts of the ocean and even of inland seas are a thousand fathoms or upwards in depth, it is a matter of no moment to the animate creation that vast tracts should be heaved up many fathoms at certain intervals, or should subside to the same amount. Neither can any material revolution be produced in South America either in the terrestrial or the marine plants or animals by a series of shocks on the coast of Chili, each of which, like that of Penco, in 1751, should uplift the coast about twenty-five feet. Nor if the ground sinks fifty feet at a time, as in the

harbour of Port Royal, in Jamaica, in 1692, will such alterations of level work any general fluctuations in the state of organic beings inhabiting the West India islands, or the Caribbean Sea.

It is only when these subterranean powers, by shifting gradually the points where their principal force is developed, happen to strike upon some particular region where a slight change of level immediately affects the distribution of land and water, or the state of the climate, or the barriers between distinct groups of species over extensive areas, that the rate of fluctuation becomes accelerated, and may, in the course of a few years or centuries, work mightier changes than had been experienced in myriads of antecedent years.

Thus, for example, a repetition of subsidences causing the narrow isthmus of Panama to sink down a few hundred feet, would, in a few centuries, bring about a great revolution in the state of the animate creation in the western hemisphere. Thousands of aquatic species would pass, for the first time, from the Caribbean Sea into the Pacific; and thousands of others, before peculiar to the Pacific Ocean, would make their way into the Caribbean Sea, the Gulf of Mexico, and the Atlantic. A considerable modification would probably be occasioned by the same event in the direction or volume of the Gulf stream, and thereby the temperature of the sea and the contiguous lands might be altered as far as the influence of that current extends. A change of climate might thus be produced in the ocean from Florida to Spitzbergen, and in many countries of North America, Europe, and Greenland. Not merely the heat, but the quantity of rain which falls, would be altered in certain districts, so that many species would be excluded from tracts where they before flourished: others would be

reduced in number; and some would thrive more and multiply. The seeds also and the fruits of plants would no longer be drifted in precisely the same directions, nor the eggs of aquatic animals; neither would species be any longer impeded in their migrations towards particular stations before shut out from them by their inability to cross the mighty current.

Let us take another example from a part of the globe which is at present liable to suffer by earthquakes, namely, the low sandy tract which intervenes between the Sea of Azof and the Caspian. If there should occur a sinking down to a trifling amount, and such ravines should be formed as might be produced by a few earthquakes, not more considerable than have fallen within our limited observation during the last 150 years, the waters of the Sea of Azof would pour rapidly into the Caspian, which, according to the measurements lately made by the Academy of St. Petersburg, is 108 feet below the level of the Black Sea.* The Sea of Azof would immediately borrow from the Black Sea, that sea again from the Mediterranean, and the Mediterranean from the Atlantic, so that an inexhaustible current would pour down into the low tracts of Asia bordering the Caspian, by which all the sandy salt steppes adjacent to that sea would be inundated. An area of several thousand square leagues, now below the level of the Mediterranean, would be converted from land into sea.

The diluvial waters would reach the salt lake of Aral, nor stop until their eastern shores were bounded by the high land which in the steppe of the Kirghis connects the Altay with the Himalaya Mountains. Saratof,

* See a note on this subject, Book I. chap. x.

Orenburg, and the low regions of the Oxus, and Jaxartes, would be submerged. A few years, perhaps a few months, might suffice for the accomplishment of this great revolution in the geography of the interior of Asia; and it is impossible for those who believe in the permanence of the energy with which existing causes now act, not to anticipate analogous events again and again in the course of future ages.

Illustration derived from the elevation of land.— Let us next imagine a few cases of the elevation of land of small extent at certain critical points, as, for example, in the shallowest part of the Straits of Gibraltar, where the deepest soundings from the African to the European side give only 220 fathoms. In proportion as this submarine barrier of rock was upheaved, the whole channel would be contracted in width and depth, and the volume of water which the current constantly flowing from the Atlantic pours into the Mediterranean would be lessened. But the loss of the inland sea by evaporation would remain the same; so that being no longer able to draw on the ocean for a supply sufficient to restore its equilibrium, it must sink, and leave dry a certain portion of land around its borders. The current which now flows constantly out of the Black Sea into the Mediterranean would then rush in more rapidly, and the level of the Mediterranean would be thereby prevented from falling so low; but the level of the Black Sea would, for the same reason, sink; so that when, by a continued series of elevatory movements, the Straits of Gibraltar had become completely closed up, we might expect large and level sandy steppes to surround both the Black Sea and Mediterranean, like those occurring at present on the skirts of the Caspian, and the Lake of Aral. The geographical

range of hundreds of aquatic species would be thereby circumscribed, and that of hundreds of terrestrial plants and animals extended.

A line of submarine volcanos crossing the channel of some strait, and gradually choking it up with ashes and lava, might produce a new barrier as effectually as a series of earthquakes; especially if thermal springs, charged with carbonate of lime, silica, and other mineral ingredients, should promote the rapid multiplication of corals and shells, and cement them together with solid matter precipitated during the intervals between eruptions. Suppose in this manner a stoppage to be caused of the Bahama channel between the bank of that name and the coast of Florida. This insignificant revolution, confined to a mere spot in the bottom of the ocean, would, by diverting the main current of the Gulf stream, give rise to extensive changes in the climate and distribution of animals and plants inhabiting the northern hemisphere.

Illustration from the formation of new islands.— A repetition of elevatory movements of earthquakes might continue over an area as extensive as Europe, for thousands of ages, at the bottom of the ocean, in certain regions, and produce no visible effects; whereas, if they should operate in some shallow parts of the Pacific, amid the coral archipelagos, they would soon give birth to a new continent. Hundreds of volcanic islands may be thrown up, and become covered with vegetation, without causing more than local fluctuations in the animate world; but if a chain like the Aleutian archipelago, or the Kurile Isles, run for a distance of many hundred miles, so as to form an almost uninterrupted communication between two continents, or two distant islands, the migrations of plants, birds,

insects, and even of some quadrupeds, may cause, in a short time, an extraordinary series of revolutions tending to augment the range of some animals and plants, and to limit that of others. A new archipelago might be formed in the Mediterranean, the Bay of Biscay, and a thousand other places, and might produce less important events than one rock which should rise up between Australia and Java, so placed that winds and currents might cause an interchange of the plants, insects, and birds.

From the wearing through of an Isthmus.—If we turn from the igneous to the aqueous agents, we find the same tendency to an irregular rate of change, naturally connected with the strictest uniformity in the energy of those causes. When the sea, for example, gradually encroaches upon both sides of a narrow isthmus, as that of Sleswick, separating the North Sea from the Baltic, where, as before stated, the cliffs on both the opposite coasts are wasting away,* no material alteration results for thousands of years, save only that there is a progressive conversion of a small strip of land into water. A few feet only, or a few yards, are annually removed; but when, at last, the partition shall be broken down, and the tides of the ocean shall enter by a direct passage into the inland sea, instead of going by a circuitous route through the Cattegat, a body of salt water will sweep up as far as the Gulfs of Bothnia and Finland, the waters of which are now brackish, or almost fresh; and this revolution will be attended by the local annihilation of many species.

Similar consequences must have resulted, on a small scale, when the sea opened its way through the isthmus

* See Vol. II. p. 90.

of Staveren in the thirteenth century, forming a union between an inland lake and the ocean, and opening, in the course of one century, a shallow strait, more than half as wide as the narrowest part of that which divides England from France.

Changes in physical geography which must occasion extinction of species.— It will almost seem superfluous, after I have thus traced the important modifications in the condition of living beings which flow from changes of trifling extent, to argue that entire revolutions might be brought about, if the climate and physical geography of the whole globe were greatly altered. It has been stated, that species are in general local, some being confined to extremely small spots, and depending for their existence on a combination of causes, which, if they are to be met with elsewhere, occur only in some very remote region. Hence it must happen that, when the nature of these localities is changed, the species will perish; for it will rarely happen that the cause which alters the character of the district will afford new facilities to the species to establish itself elsewhere.

African desert.— If we attribute the origin of a great part of the desert of Africa to the gradual progress of moving sands, driven eastward by the westerly winds, we may safely infer that a variety of species must have been annihilated by this cause alone. The sand-flood has been inundating, from time immemorial, some of the rich lands on the west of the Nile; and we have only to multiply this effect a sufficient number of times, in order to understand how, in the lapse of ages, a whole group of terrestrial animals and plants may become extinct.

The African desert, without including Bornou and Darfour, extends, according to the calculation of Humboldt, over 194,000 square leagues; an area nearly three times as great as that of France. In a small portion of so vast a space, we may infer from analogy that there were many peculiar species of plants and animals which must have been banished by the sand, and their habitations invaded by the camel, and by birds and insects formed for the arid sands.

There is evidently nothing in the nature of the catastrophe to favour the escape of the former inhabitants to some adjoining province; nothing to weaken, in the bordering lands, that powerful barrier against emigration — pre-occupancy. Nor, even if the exclusion of a certain group of species from a given tract were compensated by an extension of their range over a new country, would that circumstance tend to the conservation of species in general; for the extirpation would merely then be transferred to the region so invaded. If it be imagined, for example, that the aboriginal quadrupeds, birds, and other animals of Africa, emigrated in consequence of the advance of drift-sand, and colonized Arabia, the indigenous Arabian species must have given way before them, and have been reduced in number or destroyed.

Let us next suppose that, in some central and more elevated parts of the great African desert, the upheaving power of subterranean movements should be exerted throughout an immense series of ages, accompanied, at certain intervals, by volcanic eruptions, such as gave rise at once, in 1755, to a mountain 1600 feet high, on the Mexican plateau. When the continued repetition of these events had caused a mountain-

chain, it is obvious that a complete transformation in the state of the climate would be brought about throughout a vast area.

We may imagine the summits of the new chain to rise so high as to be covered, like Mount Atlas, for several thousand feet, with snow, during a great part of the year. The melting of these snows, during the greatest heat, would cause the rivers to swell in the season when the greatest drought now prevails; the waters, moreover, derived from this source, would always be of lower temperature than the surrounding atmosphere, and would thus contribute to cool the climate. During the numerous earthquakes and volcanic eruptions supposed to accompany the gradual formation of the chain, there would be many floods caused by the bursting of temporary lakes, and by the melting of snows by lava. These inundations might deposit alluvial matter far and wide over the original sands, as the country assumed varied shapes, and was modified again and again by the moving power from below, and the aqueous erosion of the surface above. At length the Sahara might be fertilized, irrigated by rivers and streamlets intersecting it in every direction, and covered by jungle and morasses; so that the animals and plants which now people Northern Africa would disappear, and the region would gradually become fitted for the reception of a population of species perfectly dissimilar in their forms, habits, and organization.

There are always some peculiar and characteristic features in the physical geography of each large division of the globe; and on these peculiarities the state of animal and vegetable life is dependent. If,

therefore, we admit incessant fluctuations in the physical geography, we must, at the same time, concede the successive extinction of terrestrial and aquatic species to be part of the economy of our system. When some great class of *stations* is in excess in certain latitudes, as, for example, in wide savannahs, arid sands, lofty mountains, or inland seas, we find a corresponding development of species adapted for such circumstances. In North America, where there is a chain of vast inland lakes of fresh water, we find an extraordinary abundance and variety of aquatic birds, fresh-water fish, testacea, and small amphibious reptiles, fitted for such a climate. The greater part of these would perish if the lakes were destroyed,— an event that might be brought about by some of the least of those important revolutions contemplated in geology. It might happen that no fresh-water lakes of corresponding magnitude might then exist on the globe; or that, if they occurred elsewhere, they might be situated in New Holland, Southern Africa, Eastern Asia, or some region so distant as to be quite inaccessible to the North American species; or they might be situated within the tropics, in a climate uninhabitable by creatures fitted for a temperate zone; or, finally, we may presume that they would be pre-occupied by *indigenous* tribes.

A vivid description has been given by Mr. Darwin and Sir W. Parish of the great droughts which have sometimes visited the Pampas of South America, for three or four years in succession, during which an incredible number of wild animals, cattle, horses, and birds, have perished from want of food and water. Several hundred thousand animals were drowned in the Parana

alone, having rushed into the river to drink, and being too much exhausted by hunger to escape.* Such droughts are often attended in South America and other hot climates by wide-spreading conflagrations, caused by lightning, which fires the dried grass and brushwood. Thus quadrupeds, birds, insects, and other creatures, are destroyed by myriads. How many species, both of the animal and vegetable world, which once flourished in the country between the valley of the Parana and the straits of Magellan, may not have been annihilated, since the first drought or first conflagration began!

To pursue this train of reasoning farther is unnecessary; the geologist has only to reflect on what has been said of the habitations and stations of organic beings in general, and to consider them in relation to those effects which were contemplated in the second book, as resulting from the igneous and aqueous causes now in action, and he will immediately perceive that, amidst the vicissitudes of the earth's surface, species cannot be immortal, but must perish, one after the other, like the individuals which compose them. There is no possibility of escaping from this conclusion, without resorting to some hypothesis as violent as that of Lamarck, who imagined, as we have before seen, that species are each of them endowed with indefinite powers of modifying their organization, in conformity to the endless changes of circumstances to which they are exposed.

* Darwin's Journal, p. 156. Sir W. Parish, Buenos Ayres, &c. pp. 371. and 151.

Effects of a general Alteration in Climate on the Distribution of Species.

Some of the effects which must attend every general alteration of *climate* are sufficiently peculiar to claim a separate consideration before concluding the present chapter.

I have before stated that, during seasons of extraordinary severity, many northern birds, and in some countries many quadrupeds, migrate southwards. If these cold seasons were to become frequent, in consequence of a gradual and general refrigeration of the atmosphere, such migrations would be more and more regular, until, at length, many animals, now confined to the arctic regions, would become the tenants of the temperate zone; while the inhabitants of the temperate zone would approach nearer to the equator. At the same time, many species previously established on high mountains would begin to descend, in every latitude, towards the middle regions; and those which were confined to the flanks of mountains would make their way into the plains. Analogous changes would also take place in the vegetable kingdom.

If, on the contrary, the heat of the atmosphere be on the increase, the plants and animals of low grounds would ascend to higher levels, the equatorial species would migrate into the temperate zone, and those of the temperate into the arctic circle.

But although some species might thus be preserved, every great change of climate must be fatal to many which can find no place of retreat when their original habitations become unfit for them. For if the general temperature be on the rise, then there is no cooler region whither the polar species can take refuge; if it

be on the decline, then the animals and plants previously established between the tropics have no resource. Suppose the general heat of the atmosphere to increase, so that even the arctic region became too warm for the musk-ox and rein-deer, it is clear that they must perish; so if the torrid zone should lose so much of its heat by the progressive refrigeration of the earth's surface as to be an unfit habitation for apes, boas, bamboos, and palms, these tribes of animals and plants, or, at least, most of the species now belonging to them, would become extinct, for there would be no warmer latitudes for their reception.

It will follow, therefore, that as often as the climates of the globe are passing from the extreme of heat to that of cold — from the summer to the winter of the great year before alluded to* — the migratory movement will be directed constantly from the poles towards the equator; and for this reason the species inhabiting parallel latitudes, in the northern and southern hemispheres, must become widely different. For I assume on grounds before explained, that the original stock of each species is introduced into one spot of the earth only, and, consequently, no species can be at once indigenous in the arctic and antarctic circles.†

But when, on the contrary, a series of changes in the physical geography of the globe, or any other supposed cause, occasions an elevation of the general temperature, — when there is a passage from the winter to one of the vernal or summer seasons of the great cycle of climate, — then the order of the migratory movement is inverted. The different species of ani-

* Book I. chap. vii. † See chap. viii.

mals and plants direct their course from the equator towards the poles; and the northern and southern hemispheres may become peopled to a great degree by identical species. Such is not the actual state of the inhabited earth, as I have already shown in my sketch of the geographical distribution of its living productions; and this fact adds an additional proof to the geological evidence, derived from independent sources, that the general temperature has been cooling down during the epochs which immediately preceded our own.

I do not mean to speculate on the entire transposition of a group of animals and plants from tropical to polar latitudes, or the reverse, as a probable, or even possible, event; for although we may believe the mean annual temperature of one zone to be transferable to another, we know that the same climate cannot be so transferred. Whatever be the general temperature of the earth's surface, comparative equability of heat will characterize the tropical regions; while great periodical variations will belong to the temperate, and still more to the polar, latitudes. These, and many other peculiarities connected with heat and light, depend on fixed astronomical causes, such as the motion of the earth and its position in relation to the sun, and not on those fluctuations of its surface, which may influence the general temperature.

Among many obstacles to such extensive transference of habitations we must not forget the immense lapse of time required, according to the hypothesis before suggested, to bring about a considerable change in climate. During a period so vast, the other causes of extirpation, before enumerated, would exert so powerful an influence as to prevent all, save a very

few hardy species, from passing from equatorial to polar regions, or from the tropics to the pole.*

But the power of accommodation to new circumstances is great in certain species, and might enable many to pass from one zone to another, if the mean annual heat of the atmosphere and the ocean were greatly altered. To the marine tribes, especially, such a passage would be possible; for they are less impeded in their migrations by barriers of land, than are the terrestrial by the ocean. Add to this, that the temperature of the ocean is much more uniform than that of the atmosphere investing the land; so that we may easily suppose that most of the testacea, fish, and other classes, might pass from the equatorial into the temperate regions, if the mean temperature of those regions were transposed, although a second expatriation of these species of tropical origin into the arctic and antarctic circles would probably be impossible.

On the principles above explained, if we found that at some former period, as when, for example, our carboniferous strata were deposited, the same tree-ferns and other plants inhabited the regions now occupied by Europe and Van Diemen's Land, we should suspect that the species in question had, at some antecedent period, inhabited lands within the tropics, and that an increase of the mean annual heat had caused them to emigrate into both the temperate zones. There are no geological data, however, as yet obtained, to warrant the opinion that such identity of species existed in the two hemispheres in the era in question.

Let us now consider more particularly the effect of vicissitudes of climate in causing one species to give way before the increasing numbers of some other.

* See Book I. chap. vi. vii. and viii.

When temperature forms the barrier which arrests the progress of an animal or plant in a particular direction, the individuals are fewer and less vigorous as they approach the extreme confines of the geographical range of the species. But these stragglers are ready to multiply rapidly on the slightest increase or diminution of heat that may be favourable to them, just as particular insects increase during a hot summer, and certain plants and animals gain ground after a series of congenial seasons.

In almost every district, especially if it be mountainous, there are a variety of species the limits of whose habitations are conterminous, some being unable to proceed farther without encountering too much heat, others too much cold. Individuals, which are thus on the borders of the regions proper to their respective species, are like the outposts of hostile armies, ready to profit by every slight change of circumstances in their favour, and to advance upon the ground occupied by their neighbours and opponents.

The proximity of distinct climates, produced by the inequalities of the earth's surface, brings species possessing very different constitutions into such immediate contact, that their naturalizations are very speedy whenever opportunities of advancing present themselves. Many insects and plants, for example, are common to low plains within the arctic circle, and to lofty mountains in Scotland and other parts of Europe. If the climate, therefore, of the polar regions were transferred to our own latitudes, the species in question would immediately descend from these elevated stations to overrun the low grounds. Invasions of this kind, attended by the expulsion of the pre-öccupants, are almost instantaneous, because the change of tem-

perature not only places the one species in a more favourable position, but renders the others sickly and almost incapable of defence.

These changes inconsistent with the theory of transmutation.— Lamarck, when speculating on the transmutation of species, supposed every modification in organization and instinct to be brought about slowly and insensibly in an indefinite lapse of ages.* But he does not appear to have sufficiently considered how much every alteration in the physical condition of the habitable surface changes the relations of a great number of co-existing species, and that some of these would be ready instantly to avail themselves of the slightest change in their favour, and to multiply to the injury of others. Even if we thought it possible that the palm or the elephant, which now flourish in equatorial regions, could ever learn to bear the variable seasons of our temperate zone, or the rigours of an arctic winter, we might, with no less confidence, affirm, that they must perish before they had time to become habituated to such new circumstances. That they would be displaced by other species as often as the climate varied, may be inferred from the data before explained respecting the local extermination of species produced by the multiplication of others.

Suppose the climate of the highest part of the woody zone of Etna to be transferred to the sea-shore at the base of the mountain, no botanist would anticipate that the olive, lemon-tree, and prickly pear (*Cactus Opuntia*), would be able to contend with the oak and chestnut, which would begin forthwith to descend to a lower level; or that these last would be

* See p. 8.

able to stand their ground against the pine, which would also, in the space of a few years, begin to occupy a lower position. We might form some kind of estimate of the time which might be required for the migrations of these plants; whereas we have no data for concluding that any number of thousands of years would be sufficient for one step in the pretended metamorphosis of one species into another, possessing distinct attributes and qualities.

This argument is applicable not merely to *climate*, but to any other cause of mutation. However slowly a lake may be converted into a marsh, or a marsh into a meadow, it is evident that before the lacustrine plants can acquire the power of living in marshes, or the marsh-plants of living in a less humid soil, other species, already existing in the region, and fitted for these several stations, will intrude and keep possession of the ground. So, if a tract of salt water becomes fresh by passing through every intermediate degree of brackishness, still the marine mollusks will never be permitted to be gradually metamorphosed into fluviatile species; because long before any such transformation can take place by slow and insensible degrees, other tribes, already formed to delight in brackish or fresh water, will avail themselves of the change in the fluid, and will, each in their turn, monopolize the space.

It is idle, therefore, to dispute about the abstract possibility of the conversion of one species into another, when there are known causes so much more active in their nature, which must always intervene and prevent the actual accomplishment of such conversions. A faint image of the certain doom of a species less fitted to struggle with some new condition in a region which it previously inhabited, and where it has to contend

with a more vigorous species, is presented by the extirpation of savage tribes of men by the advancing colony of some civilized nation. In this case the contest is merely between two different *races* — two varieties, moreover, of a species which exceeds all others in its aptitude to accommodate its habits to the most extraordinary variations of circumstances. Yet few future events are more certain than the speedy extermination of the Indians of North America and the savages of New Holland in the course of a few centuries, when these tribes will be remembered only in poetry, history, or tradition.

CHAPTER XI.

EXTINCTION AND CREATION OF SPECIES.

Theory of the successive extinction of species consistent with a limited geographical distribution — Opinions of botanists respecting the centres from which plants have been diffused — Whether there are grounds for inferring that the loss, from time to time, of certain animals and plants, is compensated by the introduction of new species? — Whether any evidence of such new creations could be expected within the historical era? — The question whether the existing species have been created in succession must be decided by geological monuments.

Successive Extinction of Species consistent with their limited Geographical Distribution.

In the preceding chapters I have pointed out the strict dependence of each species of animal and plant on certain physical conditions in the state of the earth's surface, and on the number and attributes of other organic beings inhabiting the same region. I have also endeavoured to show that all these conditions are in a state of continual fluctuation, the igneous and aqueous agents remodelling, from time to time, the physical geography of the globe, and the migrations of species causing new relations to spring up successively between different organic beings. I have deduced as a corollary, that the species existing at any particular period must, in the course of ages, become

extinct one after the other. "They must die out," to borrow an emphatical expression from Buffon; "because Time fights against them."

If the views which I have taken are just, there will be no difficulty in explaining why the habitations of so many species are now restrained within exceedingly narrow limits. Every local revolution, such as those contemplated in the preceding chapter, tends to circumscribe the range of some species, while it enlarges that of others; and if we are led to infer that new species originate in one spot only, each must require time to diffuse itself over a wide area. It will follow, therefore, from the adoption of this hypothesis, that the recent origin of some species, and the high antiquity of others, are equally consistent with the general fact of their limited distribution, some being local, because they have not existed long enough to admit of their wide dissemination; others, because circumstances in the animate or inanimate world have occurred to restrict the range which they may once have obtained.

As considerable modifications in the relative levels of land and sea have taken place in certain regions since the existing species were in being, we can feel no surprise that the zoologist and botanist have hitherto found it difficult to refer the geographical distribution of species to any clear and determinate principles, since they have usually speculated on the phenomena, upon the assumption that the physical geography of the globe had undergone no material alteration since the introduction of the species now living. So long as this assumption was made, the facts relating to the geography of plants and animals appeared capricious in the extreme, and by many the subject was pro-

nounced to be so full of mystery and anomalies, that the establishment of a satisfactory theory was hopeless.

Centres from which plants have been diffused. — Some botanists conceived, in accordance with the hypothesis of Willdenow, that mountains were the centres of creation from which the plants now inhabiting large continents have radiated; to which De Candolle and others, with much reason, objected, that mountains, on the contrary, are often the barriers between two provinces of distinct vegetation. The geologist who is acquainted with the extensive modifications which the surface of the earth has undergone in very recent geological epochs, may be able, perhaps, to reconcile both these theories in their application to different regions.

A lofty range of mountains, which is so ancient as to date from a period when the species of animals and plants differed from those now living, will naturally form a barrier between contiguous provinces; but a chain which has been raised, in great part, within the epoch of existing species, and around which new lands have arisen from the sea within that period, will be a centre of peculiar vegetation.

"In France," observes De Candolle, "the Alps and Cevennes prevent a great number of the plants of the south from spreading themselves to the northward; but it has been remarked that some species have made their way through the gorges of these chains, and are found on their northern sides, principally in those places where they are lower and more interrupted."* Now the chains here alluded to have probably been of

* Essai Elémentaire, &c., p. 46.

considerable height ever since the era when the existing vegetation began to appear, and were it not for the deep fissures which divide them, they might have caused much more abrupt terminations to the extension of distinct assemblages of species.

Parts of the Italian peninsula, on the other hand, have gained a considerable portion of their present height, since a majority of the marine species now inhabiting the Mediterranean, and probably, also, since the terrestrial plants of the same region, were in being. Large tracts of land have been added, both on the Adriatic and Mediterranean side, to what orginally constituted a much narrower range of mountains, if not a chain of islands running nearly north and south, like Corsica and Sardinia. It may therefore be presumed that the Apennines have been a centre whence species have diffused themselves over the contiguous *lower* and *newer* regions. In this and all analogous situations, the doctrine of Willdenow, that species have radiated from the mountains as from centres, may be well founded.

Introduction of New Species.

If the reader should infer, from the facts laid before him in the preceding chapters, that the successive extinction of animals and plants may be part of the constant and regular course of nature, he will naturally inquire whether there are any means provided for the repair of these losses? Is it part of the economy of our system that the habitable globe should, to a certain extent, become depopulated both in the ocean and on the land; or that the variety of species should diminish until some new era arrives when a new and extraordinary effort of creative energy is to be displayed?

Or is it possible that new species can be called into being from time to time, and yet that so astonishing a phenomenon can escape the observation of naturalists?

Humboldt has characterized these subjects as among the mysteries which natural science cannot reach; and he observes that the investigation of the origin of beings does not belong to zoological or botanical geography. To geology, however, these topics do strictly appertain; and this science is chiefly interested in inquiries into the state of the animate creation as it now exists, with a view of pointing out its relations to antecedent periods when its condition was different.

Before offering any hypothesis towards the solution of so difficult a problem, let us consider what kind of evidence we ought to expect, in the present state of science, of the first appearance of new animals or plants, if we could imagine the successive creation of species to constitute, like their gradual extinction, a regular part of the economy of nature.

In the first place, it is obviously more easy to prove that a species, once numerously represented in a given district, has ceased to be, than that some other which did not pre-exist has made its appearance — assuming always, for reasons before stated, that single stocks only of each animal and plant are originally created, and that individuals of new species do not suddenly start up in many different places at once.

So imperfect has the science of natural history remained down to our own times, that, within the memory of persons now living, the numbers of known animals and plants have been doubled, or even quadrupled, in many classes. New and often conspicuous species are annually discovered in parts of the old

continent, long inhabited by the most civilized nations. Conscious, therefore, of the limited extent of our information, we always infer, when such discoveries are made, that the beings in question had previously eluded our research; or had at least existed elsewhere, and only migrated at a recent period into the territories where we now find them. It is difficult, even in contemplation, to anticipate the time when we shall be entitled to make any other hypothesis in regard to all the marine tribes, and to by far the greater number of the terrestrial;—such as birds, which possess such unlimited powers of migration; insects which, besides their numbers, are also so capable of being diffused to vast distances; and cryptogamous plants, to which, as to many other classes, both of the animal and vegetable kingdom, similar observations are applicable.

What kind of evidence of new creations could be expected?—What kind of proofs, therefore, could we reasonably expect to find of the origin at a particular period of a new species?

Perhaps it may be said in reply that, within the last two or three centuries, some forest tree or new quadruped might have been observed to appear suddenly in those parts of England or France which had been most thoroughly investigated;—that naturalists might have been able to show that no such living being inhabited any other region of the globe, and that there was no tradition of any thing similar having before been observed in the district where it had made its appearance.

Now, although this objection may seem plausible, yet its force will be found to depend entirely on the rate of fluctuation which we suppose to prevail in the animate world, and on the proportion which such con-

spicuous subjects of the animal and vegetable kingdoms bear to those which are less known and escape our observation. There are perhaps more than a million species of plants and animals, exclusive of the microscopic and infusory animalcules, now inhabiting the terraqueous globe. The terrestrial plants may amount, says De Candolle, to somewhere between 110,000 and 120,000;* but the data on which this conjecture is founded are considered by many botanists to be vague and unsatisfactory. Sprengel only enumerated, in 1827, about 31,000 known phænogamous, and 6000 cryptogamous plants; but that naturalist omitted many, perhaps 7000 phænogamous, and 1000 cryptogamous species. Mr. Lindley is of opinion that it would be rash, in the present state of science, to speculate on the existence of more than 80,000 phænogamous, and 10,000 cryptogamous plants. "If we take," he says, in a letter to the author on this subject, "37,000 as the number of published phænogamous species, and then add, for the undiscovered species in Asia and New Holland 15,000, in Africa 10,000, and in America 18,000 we have 80,000 species; and if 7000 be the number of published cryptogamous plants, and we allow 3000 for the undiscovered species (making 10,000), there would then be, on the whole, 90,000 species."

It was supposed by Linnæus that there were four or five species of insects in the world for each phænogamous plant: but if we may judge from the relative proportion of the two classes in Great Britain, the number of insects must be still greater; for the total number of British insects, "according to the last

* Géog. des Plantes. Dict. des Sci.

census," is about 12,500,* whereas there are only 1500 phænogamous plants indigenous to our island. As the insects are much more numerous in hot countries than in our temperate latitudes, it seems difficult to avoid the conclusion that there are more than half a million species in the world.

The number of known mammifers, according to Temminck, exceeds 800, and Baron Cuvier estimated the amount of known fishes at 6000. Nearly 6000 species of birds have likewise been ascertained.† We have still to add the reptiles, and all the invertebrated animals, exclusive of insects. It remains, in a great degree, mere matter of conjecture what proportion the aquatic tribes may bear to the denizens of the land; but the habitable surface beneath the waters can hardly be estimated at less than double that of the continents and islands, even admitting that a very considerable area is destitute of life, in consequence of great depth, cold, darkness, and other circumstances. In the late polar expedition it was found that, in some regions, as in Baffin's Bay, there were marine animals inhabiting the bottom at great depths, where the temperature of the water was below the freezing point. That there is life at much greater profundities in warmer regions, may be confidently inferred. I have before stated that marine plants not only exist, but acquire vivid colours at depths where, to our senses, there would be darkness deep as night.

The ocean teems with life — the class of *polyps* alone are conjectured by Lamarck to be as strong in individuals as insects. Every tropical reef is described as covered with corals and sponges, and swarming with

* See Catalogue of Brit. Insects, by John Curtis, Esq.

† See Quarterly Review, No. xciv. p. 337.

crustacea, echini, and testacea; while almost every tide-washed rock in the world is carpeted with fuci, and supports some corallines, actiniæ, and mollusca. There are innumerable forms in the seas of the warmer zones, which have scarcely begun to attract the attention of the naturalist; and there are parasitic animals without number, three or four of which are sometimes appropriated to one genus, as to the *Balæna*, for example. Even though we concede, therefore, that the geographical range of marine species is more extensive in general than that of the terrestrial (the temperature of the sea being more uniform, and the land impeding less the migrations of the oceanic than the ocean those of the terrestrial species), yet it seems probable that the aquatic tribes far exceed in number the inhabitants of the land.

Without insisting on this point, it may be safe to assume, that, exclusive of microscopic beings, there are between one and two millions of species now inhabiting the terraqueous globe; so that if only one of these were to become extinct annually, and one new one were to be every year called into being, much more than a million of years might be required to bring about a complete revolution in organic life.

I am not hazarding at present any hypothesis as to the probable rate of change; but none will deny that when the *annual* birth and the *annual* death of one species on the globe is proposed as a mere speculation, this at least is to imagine no slight degree of instability in the animate creation. If we divide the surface of the earth into twenty regions of equal area, one of these might comprehend a space of land and water about equal in dimensions to Europe, and might contain a twentieth part of the million of species which

may be assumed to exist in the animal kingdom. In this region one species only would, according to the rate of mortality before assumed, perish in twenty years, or only five out of fifty thousand in the course of a century. But as a considerable proportion of the whole would belong to the aquatic classes, with which we have a very imperfect acquaintance, we must exclude them from our consideration; and if they constitute half of the entire number, then one species only might be lost in forty years among the terrestrial tribes. Now the mammalia, whether terrestrial or aquatic, bear so small a proportion to other classes of animals, forming less, perhaps, than one thousandth part of the whole, that if the longevity of species in the different orders were equal, a vast period must elaspe before it would come to the turn of this conspicuous class to lose one of their number. If one species only of the whole animal kingdom died out in forty years, no more than one mammifer might disappear in 40,000 years, in a region of the dimensions of Europe.

It is easy, therefore, to see, that, in a small portion of such an area, in countries, for example, of the size of England and France, periods of much greater duration must elapse before it would be possible to authenticate the first appearance of one of the larger plants and animals, assuming the annual birth and death of one species to be the rate of vicissitude in the animate creation throughout the world.

The observations of naturalists, upon living species, may, in the course of future centuries, accumulate positive data, from which an insight into the laws which govern this part of our terrestrial system may be derived; but, in the present deficiency of historical

records, we have traced up the subject to that point where geological monuments alone are capable of leading us on to the discovery of ulterior truths. To these, therefore, we must now appeal, carefully examining the strata of recent formation wherein the remains of *living* species, both animal and vegetable, are known to occur. We must study these strata in strict reference to their chronological order as deduced from their superposition, and other relations. From these sources we may learn which of the species, now our contemporaries, have survived the greatest revolutions of the earth's surface; which of them have co-existed with the greatest number of animals and plants now extinct, and which have made their appearance only when the animate world had nearly attained its present condition.

From such data we may be enabled to infer, whether species have been called into existence in succession, or all at one period; whether singly, or by groups simultaneously; whether the antiquity of man be as high as that of any of the inferior beings which now share the planet with him, or whether the human species is one of the most recent of the whole.

To some of these questions we can even now return a satisfactory answer; and with regard to the rest, we have some data to guide conjecture, and to enable us to speculate with advantage: but in order to be fully qualified to enter upon such discussions the reader must study the ample body of materials amassed by the industry of modern geologists.

CHAPTER XII.

EFFECTS PRODUCED BY THE POWERS OF VITALITY ON THE STATE OF THE EARTH'S SURFACE.

Modifications in physical geography caused by organic beings — Why the vegetable soil does not augment in thickness — The theory, that vegetation is an antagonist power counterbalancing the degradation caused by running water untenable — Conservative influence of vegetation — Rain diminished by felling of forests — Distribution of American forests dependent on direction of predominant winds — Influence of man in modifying the physical geography of the globe.

THE second branch of our inquiry, respecting changes of the organic world, relates to the processes by which the remains of animals and plants become fossil, or, to speak still more generally, to all the effects produced by the powers of vitality on the surface and shell of the earth.

Before entering on the principal division of this subject, the imbedding and preservation of animal and vegetable remains, I shall offer a few remarks on the superficial modifications caused directly by the agency of organic beings, as when the growth of certain plants covers the slope of a mountain with peat, or converts a swamp into dry land; or when vegetation prevents the soil, in certain localities, from being washed away by running water.

In considering alterations of this kind, brought about

in the physical geography of particular tracts, we are too apt to think exclusively of that part of the earth's surface which has emerged from beneath the waters, and with which alone, as terrestrial beings, we are familiar. Here the direct power of animals and plants to cause any important variation is, of necessity, very limited, except in checking the progress of that decay of which the land is the chief theatre. But if we extend our views, and, instead of contemplating the dry land, consider that larger portion which is assigned to the aquatic tribes, we discover the great influence of the living creation, in imparting varieties of conformation to the solid exterior which the agency of inanimate causes alone could not produce.

Thus, when timber is floated into the sea, it is often drifted to vast distances, and subsides in spots where there might have been no deposit, at that time and place, if the earth had not been tenanted by living beings. If, therefore, in the course of ages, a hill of wood, or lignite, be thus formed in the subaqueous regions, a change in the submarine geography may be said to have resulted from the action of organic powers. So in regard to the growth of coral reefs; it is probable that almost all the matter of which they are composed is supplied by mineral springs, which often rise up at the bottom of the sea, and which, on land, abound throughout volcanic regions hundreds of leagues in extent. The matter thus constantly given out could not go on accumulating for ever in the waters, but would be precipitated in the abysses of the sea, even if there were no polyps and testacea; but these animals arrest and secrete the carbonate of lime on the summits of submarine mountains, and form reefs many hundred feet in thickness, and hundreds of

miles in length, where, but for them, none might ever have existed.

Why the vegetable soil does not augment in thickness. — If no such voluminous masses are formed on the land, it is not from the want of solid matter in the structure of terrestrial animals and plants; but merely because, as I have so often stated, the continents are those parts of the globe where accessions of matter can scarcely ever take place — where, on the contrary, the most solid parts already formed are, each in their turn, exposed to gradual degradation. The quantity of timber and vegetable matter which grows in a tropical forest in the course of a century is enormous, and multitudes of animal skeletons are scattered there during the same period, besides innumerable land-shells and other organic substances. The aggregate of these materials, therefore, might constitute a mass greater in volume than that which is produced in any coral-reef during the same lapse of years; but, although this process should continue on the land for ever, no mountains of wood or bone would be seen stretching far and wide over the country, or pushing out bold promontories into the sea. The whole solid mass is either devoured by animals, or decomposes, as does a portion of the rock and soil on which the animals and plants are supported.

The waste of the strata themselves, accompanied by the decomposition of their organic remains, and the setting free of their alkaline ingredients, is one source from whence running water and the atmosphere may derive the materials which are absorbed by the roots and leaves of plants. Another source is the passage into a gaseous form of even the hardest parts of animals and plants which die and putrify in the air, where they are

soon resolved into the elements of which they are composed; and while a portion of these constituents is volatilized, the rest is taken up by rain-water, and sinks into the earth, or flows towards the sea; so that they enter again and again into the composition of different organic beings.

The principal elements found in plants are hydrogen, carbon, and oxygen; so that water and the atmosphere contain all of them, either in their own composition or in solution.* The constant supply of these elements is maintained not only by the putrefaction of animal and vegetable substances, and the decay of rocks, but also by the copious evolution of carbonic acid and other gases from volcanos and mineral springs, and by the effects of ordinary evaporation, whereby aqueous vapours are made to rise from the ocean, and to circulate round the globe.

It is well known that, when two gases of different specific gravity are brought into contact, even though the heavier be the lowermost, they soon become uniformly diffused by mutual absorption through the whole space which they occupy. By virtue of this law, the heavy carbonic acid finds its way upwards through the lighter air of the atmosphere, and conveys nourishment to the lichen which covers the mountain top.

The fact, therefore, that the vegetable mould which covers the earth's surface does not decrease in thickness, will not altogether bear out the argument which was founded upon it by Playfair. This vegetable soil, he observes, consists partly of loose earthy materials,

* See some good remarks on the Formation of Soils, Bakewell's Geology, chap. xviii.

easily removed, in the form of sand and gravel; partly of finer particles, suspended in the waters, which tinge those of some rivers continually, and those of all occasionally, when they are flooded. "The soil," he supposes, "although continually diminished from this cause, remains the same in quantity, or at least nearly the same, and must have done so ever since the earth was the receptacle of animal or vegetable life. The soil, therefore, is augmented from other causes, just as much, at an average, as it is diminished by that now mentioned; and this augmentation evidently can proceed from nothing but the constant and slow disintegration of the rocks."*

That the repair of the *earthy* portion of the soil can proceed, as Playfair suggests, only from the decomposition of rocks, may be admitted; but the *vegetable* matter may be supplied, and is actually furnished, in a great degree, by the absorption by plants of carbon and oxygen from the atmosphere; so that in level situations, such as in platforms that intervene between valleys where the action of running water is very trifling, the vegetable particles carried off by the rain may be perpetually restored, not by the waste of the rock below, but from the air above.

If the quantity of food consumed by terrestrial animals, and the elements imbibed by the roots and leaves of plants were derived entirely from that supply of hydrogen, carbon, oxygen, azote, and other elements, given out into the atmosphere and the waters by the putrescence of organic substances, then we might imagine that the vegetable mould would, after a series of years, neither gain nor lose a single

* Illust. of Hutt. Theory, § 103.

particle by the action of organic beings; and this conclusion is not far from the truth; but the operation which renovates the vegetable and animal mould is by no means so simple as that here supposed. Thousands of carcasses of terrestrial animals are floated down, every century, into the sea; and, together with forests of drift-timber, are imbedded in subaqueous deposits, where their elements are imprisoned in solid strata, and may there remain throughout whole geological epochs before they again become subservient to the purposes of life.

On the other hand, fresh supplies are derived by the atmosphere, and by running water, as before stated, from the disintegration of rocks and their organic contents, and through the agency of mineral springs from the interior of the earth, from whence all the elements before mentioned, which enter principally into the composition of animals and vegetables, are continually evolved. Even nitrogen has been recently found, by Dr. Daubeny, to be contained very generally in the waters of mineral springs.

Vegetation not an antagonist power counterbalancing the action of running water.—If we suppose that the copious supply from the nether regions, by springs and volcanic vents, of carbonic acid and other gases, together with the decomposition of rocks, may be just sufficient to counterbalance that loss of matter which, having already served for the nourishment of animals and plants, is annually carried down in organized forms, and buried in subaqueous strata, we concede the utmost that is consistent with probability. An opinion, however, has been expressed, that the processes of vegetable life, by absorbing various gases from the atmosphere, cause so large a mass of solid

matter to accumulate on the surface of the land, that this mass alone may constitute a great counterpoise to all the matter transported to lower levels by the aqueous agents of decay. Torrents and rivers, it is said — the waves of the sea and marine currents — act upon lines only; but the power of vegetation to absorb the elastic and non-elastic fluids circulating round the earth, extends over the whole surface of the continents. By the silent but universal action of this great antagonist power, the spoliation and waste caused by running water on the land, and by the movements of the ocean, are neutralized, and even counterbalanced.*

In opposition to these views, I conceive that we shall form a juster estimate of the influence of vegetation, if we consider it as being in a slight degree conservative, and capable of retarding the waste of land, but not of acting as an antagonist power. The vegetable mould is seldom more than a few feet in thickness, and frequently does not exceed a few inches; and we by no means find that its volume is more considerable on those parts of our continents which we can prove, by geological data, to have been elevated at more ancient periods, and where, consequently, there has been the greatest time for the accumulation of vegetable matter, produced throughout successive zoological epochs. On the contrary, these higher and older regions are more frequently denuded, so as to expose the bare rock to the action of the sun and air.

We find in the torrid zone, where the growth of plants is most rank and luxurious, that accessions of

* See Professor Sedgwick's Address to the Geological Society on the Anniversary, Feb. 1831, p. 24.

matter due to their agency are by no means the most conspicuous. Indeed it is in these latitudes, where the vegetation is most active, that for reasons to be explained in the next chapter, even those superficial peat mosses are unknown which cover a large area in some parts of our temperate zone. If the operation of animal and vegetable life could restore to the general surface of the continents a portion of the elements of those disintegrated rocks, of which such enormous masses are swept down annually into the sea, the effects would long ere this have constituted one of the most striking features in the structure and composition of our continents. All the great steppes and table-lands of the world, where the action of running water is feeble, would have become the grand repositories of organic matter, accumulated without that intermixture of earthy sediment which so generally characterizes the subaqueous strata.

Even the formation of peat in certain districts where the climate is cold and moist has not, in every instance, a conservative tendency. A peat-moss often acts like a vast sponge, absorbing water in large quantities, and swelling to the height of many yards above the surrounding country. In that case the turfy covering of the bog serves, like the skin of a bladder, to retain for a while the fluid within; and when that skin bursts, as has often happened in Ireland, and many parts of the continent, a violent inundation ensues. Examples will be mentioned in the next chapter, where the muddy torrent has hollowed out ravines, and borne along rocks and sand, in countries where such ravages could not have happened but for the existence of peat.

I may explain more clearly the kind of force which

I imagine vegetation to exert, by comparing it to the action of frost, which augments the height of some few alpine summits, by causing masses of perpetual snow to accumulate upon them, or fills up some valleys with glaciers; but although by this process of congelation the rain-water that has risen by evaporation from the sea is retained for a while in a solid form upon the land, and though some elevated spots may be protected from waste by a constant covering of ice, yet, on the other hand, the sudden melting of snow often accelerates the degradation of rock. Although every year fresh snow and ice are formed, as also more vegetable and animal matter, yet there is no increase; the one melts, the other putrefies, or is drifted down to the sea by rivers. If this were not the case, frost might be considered as an antagonist power, as well as the action of animal and vegetable life.

I have already stated that, in the known operation of the *igneous* causes, a real antagonist power is found, which may counterbalance the levelling action of running water;* and there seems no good reason for presuming that the upheaving and depressing force of earthquakes, together with the ejection of matter by volcanos, may not be fully adequate to restore that inequality of the surface which rivers and the waves and currents of the ocean annually tend to lessen. If a counterpoise be derived from this source, the quantity and elevation of land above the sea may for ever remain the same, in spite of the action of the aqueous causes, which, if thus counteracted, may never be able to reduce the surface of the earth more nearly to a state of equilibrium than that which it has now at-

* Book II. chap. i.; Vol. II. p. 475.

tained; and, on the other hand, the force of the aqueous agents themselves might thus continue for ever unimpaired. This permanence of the average intensity of the powers now in operation would account for any amount of disturbance or degradation of the earth's crust, so far as the *mere quantity* of movement or decay is concerned; provided only that indefinite periods of time are contemplated.

As to the intensity of the disturbing causes at particular epochs, their effects have as yet been studied for too short a time to enable us fully to compare the signs of ancient convulsions with the permanent monuments left in the earth's crust by the events of the last few thousand years. But, notwithstanding the small number of changes which have been witnessed and carefully recorded, observation has at least shown that our knowledge of the extent of the subterranean agency, as now developed from time to time, is in its infancy; and there can be no doubt that great partial alterations in the structure of the earth's crust are brought about in volcanic regions, without any interruption to the general tranquillity of the habitable surface.

Conservative influence of vegetation.—If, then, vegetation cannot act as an antagonist power amid the mighty agents of change which are always modifying the surface of the globe, let us next inquire how far its influence is conservative,—how far it may retard the levelling effects of running water, which it cannot oppose, much less counterbalance.

It is well known that a covering of herbage and shrubs may protect a loose soil from being carried away by rain, or even by the ordinary action of a river, and may prevent hills of loose sand from being blown

away by the wind; for the roots bind together the separate particles into a firm mass, and the leaves intercept the rain-water, so that it dries up gradually, instead of flowing off in a mass and with great velocity. The old Italian hydrogaphers make frequent mention of the increased degradation which has followed the clearing away of natural woods in several parts of Italy. A remarkable example was afforded in the Upper Val d'Arno, in Tuscany, on the removal of the woods clothing the steep declivities of the hills by which that valley is bounded. When the ancient forest laws were abolished by the Grand Duke Joseph, during the last century, a considerable tract of surface in the Cassentina (the Clausentinium of the Romans) was denuded, and immediately the quantity of sand and soil washed down into the Arno increased enormously. Frisi, alluding to such occurrences, observes, that as soon as the bushes and plants were removed, the waters flowed off more rapidly, and, in the manner of floods, swept away the vegetable soil.*

This effect of vegetation is of high interest to the geologist, when he is considering the formation of those valleys which have been principally due to the action of rivers. The spaces intervening between valleys, whether they be flat or ridgy, when covered with vegetation, may scarcely undergo the slightest waste, as the surface may be protected by the green sward of grass; and this may be renewed, in the manner before described, from elements derived from rain-water and the atmosphere. Hence, while the river is continually bearing down matter in the alluvial plain, and undermining the cliffs on each side of every valley,

* Treatise on Rivers and Torrents, p. 5. Garston's translation.

the height of the intervening rising grounds may remain stationary.

In this manner, a cone of loose scoriæ, sand, and ashes, such as Monte Nuovo, may, when it has once become densely clothed with herbage and shrubs, suffer scarcely any further dilapidation; and the perfect state of the cones of hundreds of extinct volcanos in France, Campania, Sicily, and elsewhere, may prove nothing whatever, either as to their relative or absolute antiquity. We may be enabled to infer, from the integrity of such conical hills of incoherent materials, that no flood can have passed over the countries where they are situated, since their formation; but the atmospheric action alone, in spots where there happen to be no torrents, and where the surface was clothed with vegetation, could scarcely in any lapse of ages have destroyed them.

During a tour in Spain, in 1830, I was surprised to see a district of gently undulating ground in Catalonia, consisting of red and grey sandstone, and in some parts of red marl, almost entirely denuded of herbage; while the roots of the pines, holm oaks, and some other trees, were half exposed, as if the soil had been washed away by a flood. Such is the state of the forests, for example, between Oristo and Vich, and near San Lorenzo. But, being overtaken by a violent thunder-storm, in the month of August, I saw the whole surface, even the highest levels of some flat-topped hills, streaming with mud, while on every declivity the devastation of torrents was terrific. The peculiarities in the physiognomy of the district were at once explained; and I was taught that, in speculating on the greater effects which the direct action of rain may once have produced on the surface of certain parts

of England, we need not revert to periods when the heat of the climate was *tropical.*

In the torrid zone the degradation of land is generally more rapid; but the waste is by no means proportioned to the superior quantity of rain or the suddenness of its fall, the transporting power of water being counteracted by a greater luxuriance of vegetation. A geologist who is no stranger to tropical countries observes, that the softer rocks would speedily be washed away in such regions, if the numerous roots of plants were not matted together in such a manner as to produce considerable resistance to the destructive power of the rains. The parasitical and creeping plants also entwine in every possible direction, so as to render the forests nearly impervious, and the trees possess forms and leaves best calculated to shoot off the heavy rains; which, when they have thus been broken in their fall, are quickly absorbed by the ground beneath, or, when thrown into the drainage depressions, give rise to furious torrents.*

Influence of Man in modifying the Physical Geography of the Globe.

Before concluding this chapter, I shall offer a few observations on the influence of man in modifying the physical geography of the globe; for we must class his agency among the powers of organic nature.

Felling of Forests.—The felling of forests has been attended, in many countries, by a diminution of rain, as in Barbadoes and Jamaica.† For in tropical countries, where the quantity of aqueous vapour in the atmosphere is great, but where, on the other hand, the

* De la Beche, Geol. Man., p. 184 first ed.

† Phil. Trans., vol. ii. p. 294.

direct rays of the sun are most powerful, any impediment to the free circulation of air, or any screen which shades the earth from the solar rays, becomes a source of humidity; and wherever dampness and cold have begun to be generated by such causes, the condensation of vapour continues. The leaves, moreover, of all plants are alembics, and some of those in the torrid zone have the remarkable property of distilling water, thus contributing to prevent the earth from becoming parched up.

Distribution of the American forests.—There can be no doubt, then, that the state of the climate, especially the humidity of the atmosphere, influences vegetation, and that, in its turn, vegetation re-acts upon the climate; but some writers seem to have attributed too much importance to the influence of forests, particularly those of America, as if they were the primary cause of the moisture of the climate.

The theory of a modern author on this subject "that forests exist in those parts of America only where the predominant winds carry with them a considerable quantity of moisture from the ocean," seems far more rational. In all countries, he says, "having a summer heat exceeding 70°, the presence or absence of natural woods, and their greater or less luxuriance, may be taken as a measure of the amount of humidity, and of the fertility of the soil. Short and heavy rains, in a warm country, will produce grass, which, having its roots near the surface, springs up in a few days, and withers when the moisture is exhausted; but transitory rains, however heavy, will not nourish trees; because, after the surface is saturated with water, the rest runs off, and the moisture lodged in the soil neither sinks deep enough, nor is in sufficient quantity

to furnish the giants of the forest with the necessary sustenance. It may be assumed that twenty inches of rain falling moderately, or at intervals, will leave a greater permanent supply in the soil than forty inches falling, as it sometimes does in the torrid zone, in as many hours.*

"In all regions," he continues, "where ranges of mountains intercept the course of the constant or predominant winds, the country on the windward side of the mountains will be moist, and that on the leeward dry; and hence parched deserts will generally be found on the west side of countries within the tropics, and on the east side of those beyond them, the prevailing winds in these cases being generally in opposite directions. On this principle, the position of forests in North and South America may be explained. Thus, for example, in the region within the thirtieth parallel, the moisture swept up by the trade-wind from the Atlantic is precipitated in part upon the mountains of Brazil, which are but low, and so distributed as to extend far into the interior. The portion which remains is borne westward, and, losing a little as it proceeds, is at length arrested by the Andes, where it falls down in showers on their summits. The aërial current, now deprived of all the humidity with which it can part, arrives in a state of complete exsiccation at Peru, where, consequently, no rain falls. In the same manner the Ghauts in Hindostan, a chain only three or four thousand feet high, intercept the whole moisture of the atmosphere, having copious rains on their windward side, while on the other the weather remains clear and dry. The rains in this case change regularly from the

* Maclaren, art. America, Encyc. Britannica.

west side to the east, and vice versâ, *with the monsoons.* But in the region of America, beyond the thirtieth parallel, the Andes serve as a screen to intercept the moisture brought by the prevailing winds from the Pacific Ocean: rains are copious on their summits, and in Chili on their *western* declivities; but none falls on the plains to the *eastward*, except occasionally when the wind blows from the Atlantic."*

I have been more particular in explaining these views, because they appear to place in a true light the dependence of vegetation on climate, the humidity being increased, and more uniformly diffused throughout the year, by the gradual spreading of wood.

It has been affirmed, that formerly, when France and England were covered with wood, Europe was much colder than at present; that the winters in Italy were longer, and that the Seine, and many other rivers, froze more regularly every winter than now. M. Arago, in a recent essay on this subject, has endeavoured to show, by tables of observations on the congelation of the Rhine, Danube, Rhone, Po, Seine, and other rivers, at different periods, that there is no reason to believe the cold to have been in general more intense in ancient times.† He admits, however, that the climate of Tuscany has been so far modified, by the removal of wood, as that the winters are less cold; but the summers also, he contends, are less hot than of old; and the summers, according to him, were formerly hotter in France than in our own times. His evidence is derived chiefly from documents show-

* Maclaren, art. America, Encyc. Britannica, where the position of the American forests, in accordance with this theory, is laid down in a map.

† Annuaire du Bureau des Long. 1834.

ing that wine was made three centuries ago in the Vivarais and several other provinces, at an earlier season, at greater elevations, and in higher latitudes, than are now found suitable to the vine.

In the United States of North America it is unquestionable that the rapid *clearing* of the country has rendered the winters less severe and the summers less hot; in other words, the extreme temperatures of January and July have been observed from year to year to approach nearer to each other. Whether in this case, or in France, the *mean* temperature has been raised, seems by no means as yet decided; but there is no doubt that the climate has become, as Buffon would have said, "less excessive."

The modifications of the surface, resulting from human agency, are only great when we have obtained so much knowledge of the working of the laws of nature as to be enabled to use them as powerful instruments to effect our purposes. We command nature, according to the saying of the philosopher, by obeying her laws; and for this reason we can never materially interfere with any of the great changes which either the aqueous or igneous causes are bringing about on the earth. In vain would the inhabitants of Italy strive to prevent the tributaries of the Po and Adige from bearing down, annually, an immense volume of sand and mud from the Alps and Apennines; in vain would they toil to reconvey to the mountains the mass torn from them year by year, and deposited in the form of sediment in the Adriatic. Yet they have been able to vary the distribution of this sediment over a considerable area, by embanking the rivers, and preventing the sand and mud from being spread by annual inundations over the plains.

I have explained how the form of the delta of the Po has been altered by this system of embankment, and how much more rapid have been the accessions of land at the mouths of the Po and Adige within the last twenty centuries. There is a limit, however, to these modifications, since the danger of floods augments with the increasing height of the river-beds, while the expense of maintaining the barrier is continually enhanced, as well as the difficulty of draining the low surrounding country. "In the Ganges," says Major R. H. Colebrooke, "no sooner is a slight covering of soil observed on a new sand-bank than the island is cultivated; water-melons, cucumbers, and mustard, become the produce of the first year; and rice is often seen growing near the water's edge, where the mud is in large quantity. Such islands may be swept away before they have acquired a sufficient degree of stability to resist permanently the force of the stream; but if, by repeated additions of soil, they acquire height and firmness, and natives take possession, and bring over their families, cattle, and effects. They choose the highest spots for the sites of villages, where they erect their dwellings with as much confidence as they would do on the main land; for, although the foundation is sandy, the uppermost soil, being interwoven with the roots of grass and other plants, and hardened by the sun, is capable of withstanding all attacks of the river. These islands often grow to a considerable size, and endure for the lives of the new possessors, being only at last destroyed by the same gradual process of undermining and encroachment to which the banks of the Ganges are subject." *

* Asiatic Trans., vol. vii.

If Bengal were inhabited by a nation more advanced in opulence and agricultural skill, they might, perhaps, succeed in defending these possessions against the ravages of the stream for much longer periods; but no human power could ever prevent the Ganges or the Mississippi from making and unmaking islands. By fortifying one spot against the set of the current, its force is only diverted against some other point; and, after a vast expense of time and labour, the property of individuals may be saved, but no addition would thus be made to the sum of productive land. It may be doubted whether any system could be devised so conducive to *national* wealth as the simple plan pursued by the peasants of Hindostan, who, wasting no strength in attempts to thwart one of the great operations of nature, permit the alluvial surface to be perpetually renovated, and find their losses in one place compensated in some other, so that they continue to reap an undiminished harvest from a virgin soil.

To the geologist the Gangetic islands and their migratory colonies may present an epitome of the globe as tenanted by man; for during every century we cede some territory which the earthquake has sunk, or the volcano has covered by its fiery products, or which the ocean has devoured by its waves. On the other hand, we gain possession of new lands, which rivers, tides, or volcanic ejections have formed, or which subterranean causes have upheaved from the deep. Whether the human species will outlast the whole or a great part of the continents and islands now seen above the waters, is a question far beyond the reach of our conjectures; but thus much may be inferred from geological data, — that if such should be its fate, it will be no more than has already been the lot of pre-existing

species, some of which have, ere now, outlived the form and distribution of land and sea which prevailed at the era of their birth.

I have before shown, when treating of the excavation of new estuaries in Holland by inroads of the ocean, as also of the changes on our own coasts, that although the conversion of sea into land by artificial labours may be great, yet it must always be in subordination to the great movements of the tides and currents.* If, in addition to the assistance obtained by parliamentary grants for defending Dunwich from the waves, all the resources of Europe had been directed to the same end, the existence of that port might possibly have been prolonged for many centuries.† But, in the mean time, the current would have continued to sweep away portions from the adjoining cliffs on each side, rounding off the whole line of coast into its present form, until at length the town, projecting as a narrow promontory, must have become exposed to the irresistible fury of the waves.

It is scarcely necessary to observe, that the control which man can obtain over the igneous agents is less even than that which he may exert over the aqueous. He cannot modify the upheaving or depressing force of earthquakes, or the periods or degree of violence of volcanic eruptions; and on these causes the inequalities of the earth's surface, and, consequently, the shape of the sea and land, appear mainly to depend. The utmost that man can hope to effect in this respect is occasionally to divert the course of a lava stream, and to prevent the burning matter, for a season, from overwhelming a city, or some other of the proudest works of human industry.

* Book II. chap. viii.

† Vol. II. p. 58.

No application, perhaps, of human skill and labour tends so greatly to vary the state of the habitable surface, as that employed in the drainage of lakes and marshes, since not only the *stations* of many animals and plants, but the general climate of a district, may thus be modified. It is also a kind of alteration to which it is difficult to find any thing analogous in the agency of inferior beings; for we ought always, before we decide that any part of the influence of man is novel and anomalous, carefully to consider the powers of all other animated agents which may be limited or superseded by him. Many who have reasoned on these subjects seem to have forgotten that the human race often succeeds to the discharge of functions previously fulfilled by other species; a topic on which I have already offered some hints, when explaining how the distribution and numbers of each species are dependent on the state of contemporary beings.

Suppose the growth of some of the larger terrestrial plants, or, in other words, the extent of forests, to be diminished by man, and the climate to be thereby modified, it does not follow that this kind of innovation is unprecedented. It is a change in the state of vegetation, and such may often have been the result of the appearance of new species upon the earth. The multiplication, for example, of certain insects in parts of Germany, during the last century, destroyed more trees than man, perhaps, could have felled during an equal period.

It would be rash, however, to pretend to decide how far the power of man to modify the surface may differ in kind or degree from that of other living beings; the problem is certainly more complex than

many who have speculated on such topics have imagined. If land be raised from the sea, the greatest alteration in its physical condition, which could ever arise from the influence of organic beings, would probably be produced by the first immigration of terrestrial plants, whereby the new tract would become covered with vegetation. The change next in importance would seem to be when animals first enter, and modify the proportionate numbers of certain species of plants. If there be any anomaly in the intervention of man, in farther varying the relative numbers in the vegetable kingdom, it may not so much consist in the kind or absolute quantity of alteration, as in the circumstance that a *single species*, in this case, would exert, by its superior power and universal distribution, an influence equal to that of hundreds of other terrestrial animals.

If we inquire whether man, by his direct power, or by the changes which he may give rise to indirectly, tends, upon the whole, to lessen or increase the inequalities of the earth's surface, we shall incline, perhaps, to the opinion that he is a levelling agent. In mining operations he conveys upwards a certain quantity of materials from the bowels of the earth; but, on the other hand, much rock is taken annually from the land, in the shape of ballast, and afterwards thrown into the sea, and by this means, in spite of prohibitory laws, many harbours, in various parts of the world, have been blocked up. We rarely transport heavy materials to higher levels, and our pyramids and cities are chiefly constructed of stone brought down from more elevated situations. By ploughing up thousands of square miles, and exposing a surface for part of the year to the action of the elements, we assist the

abrading force of rain, and diminish the conservative effects of vegetation.

But the aggregate force exerted by man is truly insignificant, when we consider the operations of the great physical agents, whether aqueous or igneous, of the inanimate world. If all the nations of the earth should attempt to quarry away the lava which flowed during one eruption from the Icelandic volcanos in 1783, and the two following years, and should attempt to consign it to the deepest abysses of the ocean, they might toil for thousands of years before their task was accomplished. Yet the matter borne down by the Ganges and Burrampooter, in a single year, probably very much exceeds, in weight and volume, the mass of Icelandic lava produced by that great eruption.*

* Vol. II. p. 13.

CHAPTER XIII.

INCLOSING OF FOSSILS IN PEAT, BLOWN SAND AND VOLCANIC EJECTIONS.

Division of the subject — Imbedding of organic remains in deposits on emerged land — Growth of peat — Site of ancient forests in Europe now occupied by peat — Bog iron-ore — Preservation of animal substances in peat — Miring of quadrupeds — Bursting of the Solway moss — Imbedding of organic bodies and human remains in blown sand — Moving sands of African deserts — De Luc on their recent origin — Buried temple of Ipsambul — Dried carcasses in the sands — Towns overwhelmed by sand-floods — Imbedding of organic and other remains in volcanic formations on the land.

Division of the subject.— The next subject of inquiry is the mode in which the remains of animals and plants become fossil, or are buried in the earth by natural causes. M. Constant Prevost has observed, that the effects of geological causes are divisible into two great classes; those produced on the surface during the submersion of land beneath the waters, and those which take place after its emersion. Agreeably to this classification, I shall consider, first, in what manner animal and vegetable remains become included and preserved in deposits on emerged land, or that part of the surface which is not *permanently* covered by water, whether of seas or lakes; secondly, the manner in which organic remains become imbedded in subaqueous deposits.

Under the first division, I shall treat of the following topics: — 1st, the growth of peat, and the preservation of vegetable and animal remains therein; — 2dly, the burying of organic remains in blown sand; — 3dly, of the same in the ejections and alluviums of volcanos; — 4thly, in alluviums generally, and in the ruins of landslips; — 5thly, in the mud and stalagmite of caves and fissures.

Growth of Peat, and Preservation of Vegetable and Animal Remains therein.

The generation of peat, when not completely under water, is confined to moist situations, where the temperature is low, and where vegetables may decompose without putrefying. It may consist of any of the numerous plants which are capable of growing in such *stations;* but a species of moss (*Sphagnum palustre*) constitutes a considerable part of the peat found in marshes of the north of Europe; this plant having the property of throwing up new shoots in its upper part, while its lower extremities are decaying.* Reeds, rushes, and other aquatic plants may usually be traced in peat; and their organization is often so entire that there is no difficulty in discriminating the distinct species.

Analysis of peat.—In general, says Sir H. Davy, one hundred parts of dry peat contain from sixty to ninety-nine parts of matter destructible by fire; and the residuum consists of earths usually of the same kind as the substratum of clay, marl, gravel, or rock,

* For a catalogue of the plants which contribute to the generation of peat, see Dr. Rennie on Peat, pp. 171 — 178.; and Dr. Mac Culloch's Western Isles, vol. i. p. 129.

on which they are found, together with oxide of iron. "The peat of the chalk counties of England," observes the same writer, "contains much gypsum; but I have found very little in any specimens from Ireland or Scotland, and in general these peats contain very little saline matter." * From the researches of Dr. MacCulloch, it appears that peat is intermediate between simple vegetable matter and lignite, the conversion of peat to lignite being gradual, and being brought about by the prolonged action of water.†

Peat abundant in cold and humid climates.—Peat is sometimes formed on a declivity in mountainous regions, where there is much moisture; but in such situations it rarely, if ever, exceeds four feet in thickness. In bogs, and in low grounds into which alluvial peat is drifted, it is found forty feet thick, and upwards; but in such cases it generally owes one half of its volume to the water which it contains. It has seldom, if ever, been discovered within the tropics; and it rarely occurs in the valleys, even in the south of France and Spain. It abounds more and more, in proportion as we advance farther from the equator, and becomes not only more frequent but more inflammable in northern latitudes.‡

The same phenomenon is repeated in the southern hemisphere. No peat is found in Brazil, nor even in the swampy parts of the country drained by the La Plata on the east side of South America, or in the island of Chiloe on the west; yet when we reach the 45th degree of latitude and examine the Chonos

* Irish Bog Reports, p. 209.

† System of Geology, vol. ii. p. 353.

‡ Rev. Dr. Rennie on Peat, p. 260.

Archipelago or the Falkland Islands, and Terra del Fuego, we meet with an abundant growth of this substance. Almost all plants contribute here by their decay to the production of peat, even the grasses; but it is a singular fact, says Mr. Darwin, as contrasted with what occurs in Europe, that no kind of moss enters into the composition of the South American peat, which is formed by many plants, but chiefly by that called by Brown, *Astelia pumila.**

Extent of surface covered by peat.— There is a vast extent of surface in Europe covered with peat, which, in Ireland, is said to extend over a tenth of the whole island. One of the mosses on the Shannon is described by Dr. Boate to be fifty miles long, by two or three broad; and the great marsh of Montoire, near the mouth of the Loire, is mentioned, by Blavier, as being more than fifty leagues in circumference. It is a curious and well-ascertained fact, that many of these mosses of the north of Europe occupy the place of forests of pine and oak, which have, many of them, disappeared within the historical era. Such changes are brought about by the fall of trees and the stagnation of water, caused by their trunks and branches obstructing the free drainage of the atmospheric waters, and giving rise to a marsh. In a warm climate, such decayed timber would immediately be removed by insects, or by putrefaction; but, in the cold temperature now prevailing in our latitudes, many examples are recorded of marshes originating in this source. Thus, in Mar forest, in Aberdeenshire, large trunks of Scotch fir, which had fallen from age and decay, were soon immured in peat, formed partly out of their

* Darwin's Journal, p. 349.

perishing leaves and branches, and in part from the growth of other plants. We also learn, that the overthrow of a forest by a storm, about the middle of the seventeenth century, gave rise to a peat moss near Lochbroom, in Ross-shire, where, in less than half a century after the fall of the trees, the inhabitants dug peat.* Dr. Walker mentions a similar change, when, in the year 1756, the whole wood of Drumlanrig in Dumfries-shire was overset by the wind. Such events explain the occurrence, both in Britain and on the Continent, of mosses where the trees are all broken within two or three feet of the original surface, and where their trunks all lie in the same direction.†

It may however be suggested in these cases, that the soil had become exhausted for trees, and that, on the principle of that natural rotation which prevails in the vegetable world, one set of plants died out and another succeeded. It is certainly a remarkable fact that in the Danish Islands, and in Jutland and Holstein, fir wood of various species, especially Scotch fir, is found at the bottom of the peat mosses, although it is well ascertained that for the last five centuries no coniferæ have grown wild in these countries; the coniferous trees which now flourish there having been all planted towards the close of the last century.

Nothing is more common than the occurrence of buried trees at the bottom of the Irish peat-mosses, as also in most of those of England, France, and Holland; and they have been so often observed with parts of their trunks standing erect, and with their roots fixed to the sub-soil, that no doubt can be entertained of their having generally grown on the spot. They consist,

* Dr. Rennie's Essays, p. 65. † Ibid. p. 30.

for the most part, of the fir, the oak, and the birch: where the sub-soil is clay, the remains of oak are the most abundant; where sand is the substratum, fir prevails. In the marsh of Curragh, in the Isle of Man, vast trees are discovered standing firm on their roots, though at the depth of eighteen or twenty feet below the surface. Some naturalists have desired to refer the imbedding of timber in peat-mosses to aqueous transportation, since rivers are well known to float wood into lakes; but the facts above mentioned show that, in numerous instances, such an hypothesis is inadmissible. It has, moreover, been observed, that in Scotland, as also in many parts of the Continent, the largest trees are found in those peat-mosses which lie in the least elevated regions, and that the trees are proportionally smaller in those which lie at higher levels; from which fact De Luc and Walker have both inferred, that the trees grew on the spot, for they would naturally attain a greater size in lower and warmer levels. The leaves also, and fruits of each species, are continually found immersed in the moss along with the parent trees; as, for example, the leaves and acorns of the oak, the cones and leaves of the fir, and the nuts of the hazel.

Recent origin of some peat-mosses.— In Hatfield moss, in Yorkshire, which appears clearly to have been a forest eighteen hundred years ago, fir-trees have been found ninety feet long, and sold for masts and keels of ships; oaks have also been discovered there above one hundred feet long. The dimensions of an oak from this moss are given in the Philosophical Transactions, No. 275., which must have been larger than any tree now existing in the British dominions.

In the same moss of Hatfield, as well as in that of

Kincardine, in Scotland, and several others, Roman roads have been found covered to the depth of eight feet by peat. All the coins, axes, arms, and other utensils found in British and French mosses, are also Roman; so that a considerable portion of the European peat-bogs are evidently not more ancient than the age of Julius Cæsar. Nor can any vestiges of the ancient forests described by that general, along the line of the great Roman way in Britain, be discovered, except in the ruined trunks of trees in peat.

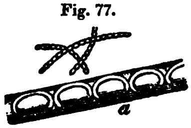
De Luc ascertained that the very site of the aboriginal forests of Hircinia, Semana, Ardennes, and several others, are now occupied by mosses and fens; and a great part of these changes have, with much probability, been attributed to the strict orders given by Severus, and other emperors, to destroy all the wood in the conquered provinces. Several of the British forests, however, which are now mosses, were cut at different periods, by order of the English parliament, because they harboured wolves or outlaws. Thus the Welsh woods were cut and burnt, in the reign of Edward I.; as were many of those in Ireland, by Henry II., to prevent the natives from harbouring in them, and harassing his troops.

It is curious to reflect that considerable tracts have, by these accidents, been permanently sterilized, and that, during a period when civilization has been making great progress, large areas in Europe have, by human agency, been rendered less capable of administering to the wants of man. Rennie observes, with truth, that in those regions alone which the Roman eagle never reached — in the remote circles of the German empire, in Poland and Prussia, and still more in Norway, Sweden, and the vast empire of Russia — can we

see what Europe was before it yielded to the power of Rome.* Desolation now reigns where stately forests of pine and oak once flourished, such as might now have supplied all the navies of Europe with timber.

Sources of bog iron-ore.—At the bottom of peat-mosses there is sometimes found a cake, or "pan," as it is termed, of oxide of iron, and the frequency of bog iron-ore is familiar to the mineralogist. The oak, which is so often found dyed black in peat, owes its colour to the same metal. From what source the iron is derived has often been a subject of discussion, until the discoveries of Ehrenberg seem at length to have removed the difficulty. He had observed in the marshes about Berlin, a substance of a deep ochre yellow passing into red, which covered the bottom of the ditches, and which, where it had become dry after the evaporation of the water, appeared exactly like oxide of iron. But under the microscope it was found to consist of slender articulated threads, which are the shields partly siliceous and partly ferruginous of an infusory animalcule, called *Gaillonella ferruginea.* There can be little doubt, therefore, that bog iron-ore consists of an aggregate of millions of these infusorial shields invisible to the naked eye.†

Fig. 77.



Gaillonella ferruginea.
a. 2000 times magnified.

Preservation of animal substances in peat.—One interesting circumstance attending the history of peat-mosses is the high state of preservation of animal substances buried in them for periods of many years. In

* Essays, &c., p. 74.

† Ehrenberg, Taylor's Scientific Mem. vol. i. part iii. p. 402.

June, 1747, the body of a woman was found six feet deep, in a peat-moor in the Isle of Axholm, in Lincolnshire. The antique sandals on her feet afforded evidence of her having been buried there for many ages: yet her nails, hair, and skin, are described as having shown hardly any marks of decay. On the estate of the Earl of Moira, in Ireland, a human body was dug up, a foot deep in gravel, covered with eleven feet of moss; the body was completely clothed, and the garments seemed all to be made of hair. Before the use of wool was known in that country, the clothing of the inhabitants was made of hair, so that it would appear that this body had been buried at that early period; yet it was fresh and unimpaired.* In the Philosophical Transactions, we find an example recorded of the bodies of two persons having been buried in moist peat, in Derbyshire, in 1674, about a yard deep, which were examined twenty-eight years and nine months afterwards; "the colour of their skin was fair and natural, their flesh soft as that of persons newly dead."†

Among other analogous facts we may mention, that in digging a pit for a well near Dulverton, in Somersetshire, many pigs were found in various postures, still entire. Their shape was well preserved, the skin, which retained the hair, having assumed a dry, membranous appearance. Their whole substance was converted into a white, friable, laminated, inodorous and tasteless substance; but which, when exposed to heat, emitted an odour precisely similar to broiled bacon.‡

* Dr. Rennie, Essays, &c., p. 521., where several other instances are referred to.

† Phil. Trans., vol. xxxviii., 1734.

‡ Dr. Rennie, Essays, &c., p. 521.

Cause of the antiseptic property of peat.—We naturally ask whence peat derives this antiseptic property? It has been attributed by some to the carbonic and gallic acids which issue from decayed wood, as also to the presence of charred wood in the lowest strata of many peat-mosses, for charcoal is a powerful antiseptic, and capable of purifying water already putrid. Vegetable gums and resins also may operate in the same way.*

The tannin occasionally present in peat is the produce, says Dr. MacCulloch, of tormentilla, and some other plants; but the quantity he thinks too small, and its occurrence too casual, to give rise to effects of any importance. He hints that the soft parts of animal bodies, preserved in peat-bogs, may have been converted into adipocire by the action of water merely; an explanation which appears clearly applicable to some of the cases above enumerated.†

Miring of quadrupeds.—The manner, however, in which peat contributes to preserve, for indefinite periods, the harder parts of terrestrial animals, is a subject of more immediate interest to the geologist. There are two ways in which animals become occasionally buried in the peat of marshy grounds; they either sink down into the semifluid mud, underlying a turfy surface, upon which they have rashly ventured, or, at other times, a bog "bursts," in the manner before described, and animals may be involved in the peaty alluvium.‡

In the extensive bogs of Newfoundland cattle are sometimes found buried with only their heads and

* Dr. Rennie, Essays, &c., p. 531.

† Syst. of Geol., vol. ii. pp. 340—346.

‡ See above, p. 248.

neck above ground; and after having remained for days in this situation, they have been drawn out by ropes and saved. In Scotland, also, cattle venturing on the "quaking moss" are often mired, or "laired," as it is termed; and in Ireland, Mr. King asserts that the number of cattle which are lost in sloughs is quite incredible.*

Solway moss.—The description given of the Solway moss will serve to illustrate the general character of these boggy grounds. That moss, observes Gilpin, is a flat area, about seven miles in circumference, situated on the western confines of England and Scotland. Its surface is covered with grass and rushes, presenting a dry crust and a fair appearance; but it shakes under the least pressure, the bottom being unsound and semi-fluid. The adventurous passenger, therefore, who sometimes in dry seasons traverses this perilous waste, to save a few miles, picks his cautious way over the rushy tussocks as they appear before him, for here the soil is firmest. If his foot slip, or if he venture to desert this mark of security, it is possible he may never more be heard of.

"At the battle of Solway, in the time of Henry VIII. (1542), when the Scotch army, commanded by Oliver Sinclair, was routed, an unfortunate troop of horse, driven by their fears, plunged into this morass, which instantly closed upon them. The tale was traditional, but it is now authenticated; a man and horse, in complete armour, having been found by peat-diggers, in the place where it was always supposed the affair had happened. The skeleton of each was well preserved, and the different parts of the armour easily distinguished."†

* Phil. Trans. vol. xv. p. 949.

† Gilpin, Observ. on Picturesque Beauty, &c., 1772.

This same moss, on the 16th of December, 1772, having been filled with water during heavy rains, rose to an unusual height, and then burst. A stream of black half-consolidated mud began at first to creep over the plain, resembling, in the rate of its progress, an ordinary lava current. No lives were lost, but the deluge totally overwhelmed some cottages, and covered 400 acres. The highest parts of the original moss subsided to the depth of about twenty-five feet; and the height of the moss, on the lowest parts of the country which it invaded, was at least fifteen feet.

Bursting of a peat-moss in Ireland.— A recent inundation in Sligo (January, 1831), affords another example of this phenomenon. After a sudden thaw of snow, the bog between Bloomfield and Geevah gave way; and a black deluge, carrying with it the contents of a hundred acres of bog, took the direction of a small stream, and rolled on with the violence of a torrent, sweeping along heath, timber, mud, and stones, and overwhelming many meadows and arable land. On passing through some boggy land, the flood swept out a wide and deep ravine, and part of the road leading from Bloomfield to St. James's Well was completely carried away from below the foundation for the breadth of 200 yards.

Bones of herbivorous quadrupeds in peat.— The antlers of large and full-grown stags are amongst the most common and conspicuous remains of animals in peat. They are not horns which have been shed; for portions of the skull are found attached, proving that the whole animal perished. Bones of the ox, hog, horse, sheep, and other herbivorous animals, also, occur; and in Ireland and the Isle of Man skeletons of a gigantic elk. M. Morren has discovered in the peat

of Flanders, the bones of otters and beavers; * but no remains have been met with belonging to those extinct quadrupeds of which the living congeners inhabit warmer latitudes, such as the elephant, rhinoceros, hippopotamus, hyæna, and tiger, though these are so common in superficial deposits of silt, mud, sand, or stalactite, in various districts throughout Great Britain. Their absence seems to imply that they had ceased to live before the atmosphere of this part of the world acquired that cold and humid character which favours the growth of peat.

Remains of ships, &c. in peat-mosses.— From the facts before mentioned, that mosses occasionally burst, and descend in a fluid state to lower levels, it will readily be seen that lakes and arms of the sea may occasionally become the receptacles of drift-peat. Of this, accordingly, there are numerous examples; and hence the alternations of clay and sand with different deposits of peat so frequent on some coasts, as on those of the Baltic and German Ocean. We are informed by Deguer that remains of ships, nautical instruments, and oars, have been found in many of the Dutch mosses; and Gerard, in his History of the Valley of the Somme, mentions that in the lowest tier of that moss was found a boat loaded with bricks, proving that those mosses were at one period navigable lakes and arms of the sea, as were also many mosses on the coast of Picardy, Zealand, and Friesland, from which soda and salt are procured.† The canoes, stone hatchets, and stone arrow-heads, found in peat in different parts of Great Britain, lead to similar conclusions.

* Bulletin de la Soc. Géol. de France, tom. ii. p. 26.

† Dr. Rennie, Essays on Peat-Moss, p. 205.

Imbedding of Human and other Remains, and Works of Art, in Blown Sand.

The drifting of sand may next be considered among the causes capable of preserving organic remains and works of art on the emerged land.

African sands.—The sands of the African deserts have been driven by the west winds over parts of the arable land of Egypt, on the western bank of the Nile, in those places where valleys open into the plain, or where there are gorges through the Libyan mountains. By similar sand-drifts the ruins of ancient cities have been buried between the Temple of Jupiter Ammon and Nubia. M. G. A. de Luc attempted to infer the recent origin of our continents, from the fact that these moving sands have arrived only in modern times at the fertile plains of the Nile. The same scourge, he said, would have afflicted Egypt for ages anterior to the times of history, had the continents risen above the level of the sea several hundred centuries before our era.* But the author proceeded in this, as in all his other chronological computations, on a multitude of gratuitous assumptions. He ought, in the first place, to have demonstrated that the whole continent of Africa was raised above the level of the sea at one period; for unless this point was established, the region from whence the sands began to move might have been the last addition made to Africa, and the commencement of the sand flood might have been long posterior to the laying dry of the greater portion of that continent. That the different parts of Europe were not all elevated at one time is now generally

* M. G. A. de Luc, Mercure de France, Sept. 1809.

admitted. De Luc should also have pointed out the depth of drift sand in various parts of the great Libyan deserts, and have shown whether the valleys of large dimensions had been filled up — how long these may have arrested the progress of the sands, and how far the flood had upon the whole advanced since the times of history.

We have seen that Sir J. G. Wilkinson is of opinion that, while the sand-drift is making aggressions at certain points upon the fertile soil of Egypt, the alluvial deposit of the Nile is advancing very generally upon the desert; and that, upon the whole, the balance is greatly in favour of the fertilizing mud.*

No mode of interment can be conceived more favourable to the conservation of monuments for indefinite periods than that now so common in the region immediately westward of the Nile. The sand which surrounded and filled the great temple of Ipsambul, first discovered by Burckhardt, and afterwards partially uncovered by Belzoni and Beechey, was so fine as to resemble a fluid when put in motion. Neither the features of the colossal figures, nor the colour of the stucco with which some were covered, nor the paintings on the walls, had received any injury from being enveloped for ages in this dry impalpable dust.†

At some future period, perhaps, when the pryamids shall have perished, the action of the sea, or an earthquake, may lay open to the day some of these buried temples. Or we may suppose the desert to remain undisturbed, and changes in the surrounding sea and land to modify the climate and the direction of the prevailing winds, so that these may then waft away

* See Book II. chap. i.

† Stratton, Ed. Phil. Journ., No. V. p. 62.

the Libyan sands as gradually as they once brought them to those regions. Thus, many a town and temple of higher antiquity than Thebes or Memphis may reappear in their original integrity, and a part of the gloom which overhangs the history of the earlier nations be dispelled.

Whole caravans are said to have been overwhelmed by the Libyan sands; and Burckhardt informs us that "after passing the Akaba, near the head of the Red Sea, the bones of dead camels are the only guides of the pilgrim through the wastes of sand."—"We did not see," says Captain Lyon, speaking of a plain near the Soudah mountains, in Northern Africa, "the least appearance of vegetation; but observed many skeletons of animals, which had died of fatigue on the desert, and occasionally the grave of some human being. All these bodies were so dried by the heat of the sun, that putrefaction appears not to have taken place after death. In recently expired animals I could not perceive the slightest offensive smell; and in those long dead, the skin with the hair on it remained unbroken and perfect, although so brittle as to break with a slight blow. The sand-winds never cause these carcasses to change their places; for, in a short time, a slight mound is formed round them, and they become stationary."*

Towns overwhelmed by sand floods.—The burying of several towns and villages in England, France, and Jutland, by blown sand is on record; thus, for example, near St. Pol de Leon, in Brittany, a whole village was completely buried beneath drift sand, so that

* Travels in North Africa in the Years 1818, 1819, and 1820, p. 83.

nothing was seen but the spire of the church.* In Jutland marine shells adhering to sea-weed are sometimes blown by the violence of the wind to the height of 100 feet and buried in similar hills of sand.

In Suffolk, in the year 1688, part of Downham was overwhelmed by sands which had broken loose about 100 years before, from a warren five miles to the south-west. This sand had, in the course of a century, travelled five miles, and covered more than 1000 acres of land.† A considerable tract of cultivated land on the north coast of Cornwall has been inundated by drift sand, forming hills several hundred feet above the level of the sea, and composed of comminuted marine shells, in which some terrestrial shells are inclosed entire. By the shifting of these sands the ruins of ancient buildings have been discovered; and in some cases where wells have been bored to a great depth, distinct strata, separated by a vegetable crust, are visible. In some places, as at New Quay, large masses have become sufficiently indurated to be used for architectural purposes. The lapidification, which is still in progress, appears to be due to oxide of iron held in solution by the water which percolates the sand.‡

Imbedding of Organic and other Remains in Volcanic Formations on the Land.

I have in some degree anticipated the subject of this section in a former volume, when speaking of the

* Mém. de l'Acad. des Sci. de Paris, 1772.—See also the case of the buried church of Eccles, above, vol. II. p. 52.

† Phil. Trans., vol. ii. p. 722.

‡ Boase on Submersion of Part of the Mount's Bay, &c., Trans. Roy. Geol. Soc. of Cornwall, vol. ii. p. 140.

buried cities around Naples, and those on the flanks of Etna.* From the facts referred to, it appeared that the preservation of human remains and works of art is frequently due to the descent of floods caused by the copious rains which accompany eruptions. These aqueous lavas, as they are called in Campania, flow with great rapidity; and in 1822 surprised and suffocated, as was stated, seven persons in the villages of St. Sebastian and Massa, on the flanks of Vesuvius.

In the tuffs, moreover, or solidified mud, deposited by these aqueous lavas, impressions of leaves and of trees have been observed. Some of those, formed after the eruption of Vesuvius in 1822, are now preserved in the museum at Naples.

Lava itself may become indirectly the means of preserving terrestrial remains, by overflowing beds of ashes, pumice, and ejected matter, which may have been showered down upon animals and plants, or upon human remains. Few substances are better non-conductors of heat than volcanic dust and scoriæ, so that a bed of such materials is rarely melted by a superimposed lava current. After consolidation, the lava affords secure protection to the lighter and more removable mass below, in which the organic relics may be enveloped. The Herculaneum tuffs containing the rolls of Papyrus, of which the characters are still legible, have, as was before remarked, been for ages covered by lava.

Another mode by which lava may tend to the conservation of imbedded remains, at least of works of human art, is by its overflowing them when it is not intensely heated, in which case they sometimes suffer little or no injury.

* Vol. II. pp. 189. 214.

Thus when the Etnean lava-current of 1669 covered fourteen towns and villages, and part of the city of Catania, it did not melt down a great number of statues and other articles in the vaults of Catania; and at the depth of thirty-five feet in the same current, on the site of Mompiliere, one of the buried towns, the bell of a church and some statues were found uninjured.*

There are several buried cities in Central India, which might probably yield a richer harvest to the antiquary than Pompeii and Herculaneum.† The city of Oujein (or Oojain) was, about fifty years before the Christian era, the seat of empire, of art, and of learning; but in the time of the Rajah Vicramaditya, it was overwhelmed, together, as tradition reports, with more than eighty other large towns in the provinces of Malwa and Bagur, "by a shower of earth." The city which now bears the name is situated a mile to the southward of the ancient town. On digging on the spot where the latter is supposed to have stood, to the depth of fifteen or eighteen feet, there are frequently discovered, says Mr. Hunter, entire brick walls, pillars of stone, and pieces of wood of an extraordinary hardness, besides utensils of various kinds, and ancient coins. Many coins are also found in the channels cut by the periodical rains, or in the beds of torrents into which they have been washed. "During our stay at Oujein, a large quantity of wheat was found by a man digging for bricks. It was, as might have been expected, almost entirely consumed, and in a state resembling charcoal. In a ravine cut by the rains, from which several stone pillars had been dug, I saw a space from twelve to fifteen feet long, and seven or eight

* Vol. II. p. 214. † Vol. II. p. 189.

high, composed of earthen vessels, broken and closely compacted together. It was conjectured, with great appearance of probability, to have been a potter's kiln. Between this place and the new town is a hollow, in which, tradition says, the river Sipparah formerly ran. It changed its course at the time the city was buried, and now runs to the westward." *

The soil which covers Oujein is described as "being of an ash-grey colour, with minute specks of black sand." †

That the "shower of earth" which is reported to have "fallen from heaven" was produced by a volcanic eruption, seems very probable, although no information has been obtained respecting the site of the vent; and the nearest volcano of which we read is that which was in eruption during the Cutch earthquake in 1819, at the distance of about thirty miles from Bhooj, the capital of Cutch, and at least 300 geographical miles from Oujein.

Captain F. Dangerfield, who accompanied Sir John Malcolm in his late expedition into Central India, states that the river Nerbuddah, in Malwa, has its channel excavated through *columnar basalt*, above which are beds of *marl* impregnated with salt. The upper of these marls is of a light colour, and from thirty to forty feet thick, and rests horizontally on the lower bed, which is of a reddish colour. Both appear from the description to be tuffs composed of the materials of volcanic ejections, and forming a covering from sixty to seventy feet deep overlying the basalt, which seems to resemble some of the currents of

* Narrative of Journey from Agra to Oujein, Asiatic Researches, vol. vi. p. 36.

† Asiatic Journal, vol. ix. p. 35.

prismatic lava in Auvergne and the Vivarais. Near the middle of this tufaceous mass, and therefore at the depth of thirty feet or more from the surface, just where the two beds of tuff meet, Captain Dangerfield was shown, near the city of Mhysir, buried bricks and large earthen vessels, said to have belonged to the ancient city of Mhysir, destroyed by the catastrophe of Oujein.*

* Sir J. Malcolm's Cent. Ind.— Geol. of Malwa, by Captain F. Dangerfield, App. No. ii. pp. 324, 325.

CHAPTER XIV.

BURYING OF FOSSILS IN ALLUVIAL DEPOSITS AND IN CAVES.

Fossils in alluvium — Effects of sudden inundations — Terrestrial animals most abundantly preserved in alluvium where earthquakes prevail — Marine alluvium — Buried town — Effects of landslips — Organic remains in fissures and caves — Form and dimensions of caverns — their probable origin — Closed basins and engulphed rivers of the Morea — Katavothra — Formation of breccias with red cement — Human remains imbedded in Morea — Intermixture, in caves of south of France and elsewhere, of human remains and bones of extinct quadrupeds, no proof of former co-existence of man with those lost species.

Alluvium. — The next subject for our consideration, according to the division before proposed, is the imbedding of organic bodies in alluvium.

The gravel, sand, and mud in the bed of a river does not often contain any animal or vegetable remains; for the whole mass is so continually shifting its place, and the attrition of the various parts is so great, that even the hardest rocks contained in it are, at length, ground down to powder. But when sand and sediment are suddenly swept by a flood, and then let fall upon the land, such an alluvium may envelop trees or the remains of animals, which, in this manner, are often permanently preserved. In the mud and sand produced by the floods in Scotland, in 1829, the dead and mutilated bodies of hares, rabbits, moles,

mice, partridges, and even the bodies of men, were found partially buried.* But in these and similar cases one flood usually effaces the memorials left by another, and there is rarely a sufficient depth of undisturbed transported matter, in any one spot, to preserve the organic remains for ages from destruction.

Where earthquakes prevail, and the levels of a country are changed from time to time, the remains of animals may more easily be inhumed and protected from disintegration. Portions of plains, loaded with alluvial accumulations by transient floods, may be gradually upraised; and, if any organic remains have been imbedded in the transported materials, they may, after such elevation, be placed beyond the reach of the erosive power of streams. In districts where the drainage is repeatedly deranged by subterranean movements, every fissure, every hollow caused by the sinking in of land, becomes a depository of organic and inorganic substances, hurried along by transient floods.

Marine alluvium.—In May, 1787, a dreadful inundation of the sea was caused at Coringa, Ingeram, and other places on the coast of Coromandel, in the East Indies, by a hurricane blowing from the N. E., which raised the waters so that they rolled inland to the distance of about twenty miles from the shore, swept away many villages, drowned more than 10,000 people, and left the country covered with marine mud, on which the carcasses of about 100,000 head of cattle were strewed. An old tradition of the natives of a similar flood, said to have happened about a century before, was, till this event, regarded as fabulous by the Euro-

* Sir T. D. Lauder, Bart., on the great Floods in Morayshire, Aug. 1829, p. 177.

pean settlers.* The same coast of Coromandel was, so late as May, 1832, the scene of another catastrophe of the same kind; and when the inundation subsided, several vessels were seen grounded in the fields of the low country about Coringa.

Many of the storms termed hurricanes have evidently been connected with submarine earthquakes, as is shown by the atmospheric phenomena attendant on them, and by the sounds heard in the ground, and the odours emitted. Such were the circumstances which accompanied the swell of the sea in Jamaica, in 1780, when a great wave desolated the western coast, and, bursting upon Savanna la Mar, swept away the whole town in an instant, so that not a vestige of man, beast, or habitation, was seen upon the surface.†

Houses and works of art in alluvial deposits. — A very ancient subterranean town, apparently of Hindoo origin, was discovered in India in 1833, in digging the Doab canal. Its site is north of Saharunpore, near the town of Behat, and 17 feet below the present surface of the country. More than 170 coins of silver and copper have already been found, and many articles in metal and earthenware. The overlying deposit consisted of about 5 feet of river sand, with a substratum, about twelve feet thick, of red alluvial clay. In the neighbourhood are several rivers and torrents, which descend from the mountains charged with vast quantities of mud, sand, and shingle; and within the memory of persons now living the modern Behat has been threatened by an inundation, which after retreating left the neighbouring country strewed over with a super-

* Dodsley's Ann. Regist., 1788.

† Edwards, Hist. of West Indies, vol. i. p. 235. ed. 1801.

ficial covering of sand several feet thick. In sinking wells in the environs, masses of shingle and boulders have been reached resembling those now in the river-channels of the same district, under a deposit of 30 feet of reddish loam. Captain Cautley, therefore, who directed the excavations, supposes that the matter discharged by torrents has gradually raised the whole country skirting the base of the lower hills; and that the ancient town, having been originally built in a hollow, was submerged by floods, and covered over with sediment 17 feet in thickness.*

We are informed by M. Boblaye, that in the Morea, the formation termed céramique, consisting of pottery, tiles, and bricks, intermixed with various works of art, enters so largely into the alluvium and vegetable soil upon the plains of Greece, and into hard and crystalline breccias which have been formed at the foot of declivities, that it constitutes an important stratum which might, in the absence of zoological characters, serve to mark our epoch in a most indestructible manner.†

Landslips.—The landslip, by suddenly precipitating large masses of rock and soil into a valley, overwhelms a multitude of animals, and sometimes buries permanently whole villages, with their inhabitants and large herds of cattle. Thus three villages, with their entire population, were covered, when the mountain of Piz fell in 1772, in the district of Treviso, in the state of Venice‡; and part of Mount Grenier, south of Chambery, in Savoy, which fell down in the year 1248, buried five parishes, including the town and church of

* Journ. of Asiat. Soc., Nos. xxv. and xxix.—1834.

† Ann. des Sci. Nat., tome xxii. p. 117. Feb. 1831.

‡ Malte-Brun's Geog., vol. i. p. 435.

St. André, the ruins occupying an extent of about nine square miles.*

The number of lives lost by the slide of the Rossberg, in Switzerland, in 1806, was estimated at more than 800, a great number of the bodies, as well as several villages and scattered houses, being buried deep under mud and rock. In the same country, several hundred cottages, with eighteen of their inhabitants and a great number of cows, goats, and sheep, were victims to the sudden fall of a bed of stones, thirty yards deep, which descended from the summits of the Diablerets in Vallais. In the year 1618, a portion of Mount Conto fell, in the county of Chiavenna in Switzerland, and buried the town of Pleurs with all its inhabitants, to the number of 2430.

It is unnecessary to multiply examples of similar local catastrophes, which however numerous they may have been in mountainous parts of Europe, within the historical period, have been, nevertheless, of rare occurrence when compared to events of the same kind which have taken place in regions convulsed by earthquakes. It is then that enormous masses of rock and earth, even in comparatively low and level countries, are detached from the sides of valleys, and cast down into the river-courses, and often so unexpectedly that they overwhelm, even in the day-time, every living thing upon the plains.

Preservation of Organic Remains in fissures and caves.

In the history of earthquakes it was shown that many hundreds of new fissures and chasms had opened in certain regions during the last 150 years,

* Bakewell, Travels in the Tarentaise, vol. i. p. 201.

some of which are described as being of unfathomable depth. We also perceive that mountain masses have been violently fractured and dislocated, during their rise above the level of the sea; and thus we may account for the existence of many cavities in the interior of the earth by the simple agency of earthquakes; but there are some caverns, especially in limestone rocks, which, although usually, if not always, connected with rents, are nevertheless of such forms and dimensions, alternately expanding into spacious chambers, and then contracting again into narrow passages, that it is difficult to conceive that they can owe their origin to the mere fracturing and displacement of solid masses.

In the limestone of Kentucky, in the basin of Green River, one of the tributaries of the Ohio, a line of underground cavities has been traced in one direction for a distance of ten miles, without any termination; and one of the chambers, of which there are many, all connected by narrow tunnels, is no less than ten acres in area, and 150 feet in its greatest height. Besides the principal series of "antres vast," there are a great many lateral embranchments not yet explored.*

The cavernous structure here alluded to is not altogether confined to calcareous rocks; for it has lately been observed in micaceous and argillaceous schist in the Grecian island of Thermia (Cythnos of the ancients), one of the Cyclades. Here also spacious halls, with rounded and irregular walls, are connected together by narrow passages or tunnels, and there are many lateral branches which have no outlet. A current of water has evidently at some period flowed through the whole, and left a muddy deposit of bluish

* Mem. by Nahum Ward, Trans. of Antiq. Soc. of Massachusetts. Holmes's Un. States, p. 438.

clay upon the floor; but the erosive action of the stream cannot be supposed to have given rise to the excavations in the first instance. M. Virlet suggests that fissures were first caused by earthquakes, and that these fissures became the chimneys or vents for the disengagement of gas, generated below by volcanic heat. Gases, he observes, such as the muriatic, sulphuric, fluoric, and others, might, if raised to a high temperature, alter and decompose the rocks which they traverse. There are signs of the former action of such vapours in rents of the micaceous schist of Thermia, and thermal springs now issue from the grottos of that island. We may suppose that afterwards the elements of the decomposed rocks were gradually removed in a state of solution by mineral waters; a theory which, according to M. Virlet, is confirmed by the effect of heated gases which escape from rents in the isthmus of Corinth, and which have greatly altered and corroded the hard siliceous and jaspideous rocks.*

When we reflect on the quantity of carbonate of lime annually poured out by mineral waters, we are prepared to admit that large cavities must, in the course of ages, be formed at considerable depths below the surface in calcareous rock.† These rocks, it will be remembered, are at once more soluble, more permeable, and more fragile, than any others, at least all the compact varieties are very easily broken by the movements of earthquakes, which would produce only flexures in argillaceous strata. Fissures once formed in limestone are not liable, as in many other formations, to become closed up by impervious clayey matter, and

* Bull. de la Soc. Géol. de France, tom. ii. p. 329.

† See Book II. chap. iv.

hence a stream of acidulous water might for ages obtain a free and unobstructed passage.*

Morea.—Nothing is more common in limestone districts than the engulphment of rivers, which, after holding a subterranean course for many miles escape again by some new outlet. As they are usually charged with fine sediment, and often with sand and pebbles where they enter, whereas they are usually pure and limpid where they flow out again, they must deposit much matter in empty spaces in the interior of the earth. In addition to the materials thus introduced, stalagmite, or carbonate of lime, drops from the roofs of caverns, and in this mixture the bones of animals washed in by rivers are often entombed. In this manner we may account for those bony breccias which we often find in caves, some of which are of high antiquity, while others are very recent and in daily progress. In no district are engulphed streams more conspicuous than in the Morea, where the phenomena attending them have been lately studied and described in great detail by M. Boblaye and his fellow-labourers of the French expedition to Greece.† Their account is peculiarly interesting to geologists, because it throws light on the red osseous breccias containing the bones of extinct quadrupeds which are so common in almost all the countries bordering the Mediterranean. It appears that the numerous caverns of the Morea occur in a compact limestone, of the age of the English chalk, immediately below which are arenaceous strata referred to the period of our green sand. In the more elevated districts of that

* See some Remarks by M. Boblaye, Ann. des Mines, 3me série, tom. iv.

† See Ann. des Mines, 3me série, tom. iv. 1833.

peninsula there are many deep land-locked valleys, or basins, closed round on all sides by mountains of fissured and cavernous limestone. The year is divided almost as distinctly as between the tropics into a rainy season, which lasts upwards of four months, and a season of drought of nearly eight months' duration. When the torrents are swollen by the rains, they rush from surrounding heights into the inclosed basins; but, instead of giving rise to lakes, as would be the case in most other countries, they are received into gulphs or chasms, called by the Greeks "Katavothra," and which correspond to what are termed "swallow-holes" in the north of England. The water of these torrents is charged with pebbles and red ochreous earth, resembling precisely the well-known cement of the osseous breccias of the Mediterranean. It dissolves in acids with effervescence, and leaves a residue of hydrated oxide of iron, granular iron, impalpable grains of silex, and small crystals of quartz. Soil of the same description abounds every where on the surface of the decomposing limestone in Greece, that rock containing in it much siliceous and ferruginous matter.

Many of the Katavothra being insufficient to give passage to all the water in the rainy season, a temporary lake is formed round the mouth of the chasm, which then becomes still farther obstructed by pebbles, sand, and red mud, thrown down from the turbid waters. The lake being thus raised, its waters generally escape through other openings, at higher levels, around the borders of the plain, constituting the bottom of the closed basin.

In some places, as at Kavaros and Tripolitza, where the principal discharge is by a gulph in the middle of the plain, nothing can be seen over the opening in

summer, when the lake dries up, but a deposit of red mud, cracked in all directions. But the Katavothron is more commonly situated at the foot of the surrounding escarpment of limestone; and in that case there is sometimes room enough to allow a person to enter, in summer, and even to penetrate far into the interior. Within is seen a suit of chambers, communicating with each other by narrow passages; and M. Virlet relates, that in one instance he observed, near the entrance, human bones imbedded in recent red mud, mingled with the remains of plants and animals of species now inhabiting the Morea. It is not wonderful, he says, that the bones of man should be met with in such receptacles; for so murderous have been the late wars in Greece, that skeletons are often seen lying exposed on the surface of the country.*

In summer, when no water is flowing into the Katavothron, its mouth, half closed up with red mud, is masked by a vigorous vegetation, which is cherished by the moisture of the place. It is then the favourite hiding-place and den of foxes and jackals; so that the same cavity serves at one season of the year for the habitation of carnivorous beasts, and at another as the channel of an engulphed river. Near the mouth of one chasm, M. Boblaye and his companions saw the carcass of a horse, in part devoured, the size of which seemed to have prevented the jackals from dragging it in: the marks of their teeth were observed on the bones, and it was evident that the floods of the ensuing winter would wash in whatsoever might remain of the skeleton.

It has been stated that the waters of all these

* Bull. de la Soc. Géol. de France, tom. iii. p. 223.

torrents of the Morea are turbid where they are engulphed; but when they come out again, often at the distance of many leagues, they are perfectly clear and limpid, being only charged occasionally with a slight quantity of calcareous sand. The points of efflux are usually near the sea-shores of the Morea, but sometimes they are submarine; and when this is the case, the sands are seen to boil up for a considerable space, and the surface of the sea, in calm weather, swells in large convex waves. It is curious to reflect, that when this discharge fails in seasons of drought, the sea may break into subterraneous caverns, and carry in marine sand and shells, to be mingled with ossiferous mud, and the remains of terrestrial animals.

In general, however, the efflux of water at these inferior openings is surprisingly uniform. It seems, therefore, that the large caverns in the interior must serve as reservoirs, and that the water escapes gradually from them, in consequence of the smallness of the rents and passages by which they communicate with the surface.

The phenomena above described are not confined to the Morea, but occur in Greece generally, and in those parts of Italy, Spain, Asia Minor, and Syria, where the formations of the Morea extend. The Copaic lake in Bœotia has no outlet, except by underground channels; and hence we can explain those traditional and historical accounts of its having gained on the surrounding plains and overflowed towns, as such floods must have happened whenever the outlet was partially choked up by mud, gravel, or the subsidence of rocks, caused by earthquakes. When speaking of the numerous fissures in the limestone of Greece, M. Boblaye reminds us of the famous earthquake of 469 B. C.,

when, as we learn from Cicero, Plutarch, Strabo, and Pliny, Sparta was laid in ruins, part of the summit of Mount Taygetus torn off, and numerous gulphs and fissures caused in the rocks of Laconia.

During the great earthquake of 1693, in Sicily, several thousand people were at once entombed in the ruins of caverns in limestone, at Sortino Vecchio; and, at the same time, a large stream, which had issued for ages from one of the grottos below that town, changed suddenly its subterranean course, and came out from the mouth of a cave lower down the valley, where no water had previously flowed. To this new point the ancient water-mills were transferred.*

When the courses of engulphed rivers are thus liable to change, from time to time, by alterations in the levels of a country, and by the rending and shattering of mountain masses, we must suppose that the dens of wild beasts will sometimes be inundated by subterranean floods, and their carcasses buried under heaps of alluvium. The bones, moreover, of individuals which have died in the recesses of caves, or of animals which have been carried in for prey, may be drifted along, and mixed up with mud, sand, and fragments of rocks, so as to form osseous breccias.

In 1833 I had an opportunity of examining the most celebrated caves of Franconia, and among others that of Rabenstein, newly discovered. Their general form, and the nature and arrangement of their contents, appeared to me to agree perfectly with the notion of their having once served as the channels of subterraneous rivers. This mode of accounting for the in-

* I learnt this from some inhabitants of Sortino, in 1829, and visited the points alluded to.

troduction of transported matter into the Franconian and other caves, filled up as they often are even to their roofs with osseous breccia, was long ago proposed by M. C. Prevost,* and seems at length to be very generally adopted. But I do not doubt that bears inhabited some of the German caves, or that the cavern of Kirkdale, in Yorkshire, was once the den of hyænas. The abundance of bony dung, associated with hyænas' bones, has been pointed out by Dr. Buckland, and with reason, as confirmatory of this opinion.

The same author observed in every cave examined by him in Germany, that deposits of mud and sand, with or without rolled pebbles and angular fragments of rock, were covered over with a *single* crust of stalagmite.† In the English caves he remarked a similar absence of *alternations* of alluvium and stalagmite. But Dr. Schmerling has discovered in a cavern at Chockier, about two leagues from Liège, three distinct beds of stalagmite, and between each of them a mass of breccia, and mud mixed with quartz pebbles, and in the three deposits the bones of extinct quadrupeds.‡

This exception does not invalidate the generality of the phenomenon pointed out by Dr. Buckland, one cause of which may perhaps be this, that if several floods pass at different intervals of time through a subterranean passage, the last, if it has power to drift along fragments of rock, will also tear up any alternating stalagmitic and alluvial beds that may have been previously formed. Another cause may be, that a particular line of caverns will rarely be so situated, in

* Mém. de la Soc. d'Hist. Nat. de Paris, tom. iv.

† Reliquiæ Diluvianæ, p. 108.

‡ Journ. de Géol., tom. i. p. 286. July, 1830.

relation to the lowest levels of a country, as to become, at two distinct epochs, the receptacle of engulphed rivers; and if this should happen, some of the caves, or at least the tunnels of communication, may at the first period be entirely choked up with transported matter, so as not to allow the subsequent passage of water in the same direction.

As the same chasms may remain open throughout periods of indefinite duration, the species inhabiting a country may in the meantime be greatly changed, and thus the remains of animals belonging to very different epochs may become mingled together in a common tomb. For this reason it is often difficult to separate the monuments of the human epoch from those relating to periods long antecedent, and it was not without great care and skill that Dr. Buckland was enabled to guard against such anachronisms in his investigation of several of the English caves. He mentions that human skeletons were found in the cave of Wokey Hole, near Wells, in the Mendips, dispersed through reddish mud and clay, and some of them united by stalagmite into a firm osseous breccia. "The spot on which they lie is within reach of the highest floods of the adjacent river, and the mud in which they are buried is evidently fluviatile."*

In speaking of the cave of Paviland on the coast of Glamorganshire, the same author states that the entire mass through which bones were dispersed appeared to have been disturbed by ancient diggings, so that the remains of extinct animals had become mixed with recent bones and shells. In the same cave was a human skeleton, and the remains of recent testacea of eatable species, which may have been carried in by man.

* Reliquiæ Diluvianæ, p. 165.

In several caverns on the banks of the Meuse, near Liège, Dr. Schmerling has found human bones in the same mud and breccia with those of the elephant, rhinoceros, bear, and other quadrupeds of extinct species. He has observed none of the dung of any of these animals; and from this circumstance, and the appearance of the mud and pebbles, he concludes that these caverns were never inhabited by wild beasts, but washed in by a current of water. As the human skulls and bones were in fragments, and no entire skeleton had been found, he does not believe that these caves were places of sepulture, but that the human remains were washed in at the same time as the bones of extinct quadrupeds.

Caverns in the South of France. — Similar associations in the south of France, of human bones and works of art, with remains of extinct quadrupeds have induced some geologists to maintain that man was an inhabitant of that part of Europe before the rhinoceros, hyæna, tiger, and other fossil species disappeared. I may first mention the cavern of Bize, in the department of Aude, where M. Marcel de Serres met with a small number of human bones mixed with those of extinct animals and with land shells. They occur in a calcareous stony mass, bound together by a cement of stalagmite. On examining the same caverns, M. Tournal found not only in these calcareous beds, but also in a black mud which overlies a red osseous mud, several human teeth, together with broken angular fragments of a rude kind of pottery, and also recent marine and terrestrial shells. The teeth preserve their enamel; but the fangs are so much altered as to adhere strongly when applied to the tongue. Of the terrestrial shells thus associated with the bones

and pottery, the most common are *Cyclostoma elegans, Bulimus decollatus, Helix nemoralis*, and *H. nitida.* Among the marine are found *Pecten jacobæus, Mytilus edulis*, and *Natica mille-punctata*, all of them eatable kinds, and which may have been brought there for food. Bones were found in the same mass belonging to three new species of deer, an extinct bear (*Ursus arctoïdeus*), and the wild bull (*Bos urus*), formerly a native of Germany.*

In the same part of France, M. de Christol has found in caverns in a tertiary limestone at Pondres and Souvignargues, two leagues north of Lunel-viel, in the department of Herault, human bones and pottery confusedly mixed with remains of the rhinoceros, bear, hyæna, and other terrestrial mammifers. They were imbedded in alluvial mud, of the solidity of calcareous tufa, and containing some flint pebbles and fragments of the limestone of the country. Beneath this mixed accumulation, which sometimes attained a thickness of thirteen feet, is the original floor of the cavern, about a foot thick, covered with bones and the dung of animals (*album græcum*), in a sandy and tufaceous cement.

The human bones in these caverns of Pondres and Souvignargues were found, upon a careful analysis, to have parted with their animal matter to as great a degree, as those of the hyæna which accompany them, and are equally brittle, and adhere as strongly to the tongue.

In order to compare the degree of alteration of these bones with those known to be of high antiquity, M. Marcel de Serres and M. Ballard, chemists of Montpellier, procured some from a Gaulish sarcopha-

* M. Marcel de Serres, Géognosie des Terrains Tertiaires, p. 64. Introduction.

gus, in the plain of Lunel, supposed to have been buried for fourteen or fifteen centuries at least. In these the cellular tissue was empty, but they were more solid than fresh bones. They did not adhere to the tongue in the same manner as those of the caverns of Bize and Pondres, yet they had lost at least three fourths of their original animal matter.

The superior solidity of the Gaulish bones to those in a fresh skeleton is a fact in perfect accordance with the observations made by Mr. Mantell on bones taken from a Saxon tumulus near Lewes.

M. Teissier has also described a cavern near Mialet, in the department of Gard, where the remains of the bear and other animals were mingled confusedly with human bones, coarse pottery, teeth pierced for amulets, pointed fragments of bone, bracelets of bronze, and a Roman urn. Part of this deposit reached to the roof of the cavity, and adhered firmly to it. The author suggests that the exterior portion of the grotto may at one period have been a den of bears, and that afterwards the aboriginal inhabitants of the country took possession of it either for a dwelling or a burial place, and left there the coarse pottery, amulets, and pointed pieces of bone. At a third period the Romans may have used the cavern as a place of sepulture or concealment, and to them may have belonged the urn and bracelets of metal. If we then suppose the course of the neighbouring river to be impeded by some temporary cause, a flood would be occasioned, which, rushing into the open grotto, may have washed all the remains into the interior caves and tunnels, heaping the whole confusedly together.*

* Bull. de la Soc. Géol. de France, tom. ii. pp. 56—63.

In the controversy which has arisen on this subject MM. Marcel de Serres, De Christol, Tournal, and others, have contended, that the phenomena of this and other caverns in the south of France prove that the fossil rhinoceros, hyæna, bear, and several other lost species, were once contemporaneous inhabitants of the country, together with man; while M. Desnoyers has supported the opposite opinion. The flint hatchets and arrow heads, he says, and the pointed bones and coarse pottery of many French and English caves, agree precisely in character with those found in the tumuli, and under the dolmens (rude altars of unhewn stone) of the primitive inhabitants of Gaul, Britain, and Germany. The human bones, therefore, in the caves which are associated with such fabricated objects, must belong not to antediluvian periods, but to a people in the same stage of civilization as those who constructed the tumuli and altars.

In the Gaulish monuments we find, together with the objects of industry above mentioned, the bones of wild and domestic animals of species now inhabiting Europe, particularly of deer, sheep, wild boars, dogs, horses, and oxen. This fact has been ascertained in Quercy, and other provinces; and it is supposed by antiquaries that the animals in question were placed beneath the Celtic altars in memory of sacrifices offered to the Gaulish divinity Hesus, and in the tombs to commemorate funeral repasts, and also from a superstition prevalent among savage nations, which induces them to lay up provisions for the manes of the dead in a future life. But in none of these ancient monuments have any bones been found of the elephant, rhinoceros, hyæna, tiger, and other quadrupeds, such as are found in caves, as might certainly have been

expected, had these species continued to flourish at the time that this part of Gaul was inhabited by man.*

We are also reminded by M. Desnoyers of a passage in Florus, in which it is related that Cæsar ordered the caves into which the Aquitanian Gauls had retreated to be closed up.† It is also on record, that so late as the eighth century, the Aquitanians defended themselves in caverns against King Pepin. As many of these caverns, therefore, may have served in succession as temples and habitations, as places of sepulture, concealment, or defence, it is easy to conceive that human bones, and those of animals, in osseous breccias of much older date, may have been swept away together, by inundations, and then buried in one promiscuous heap.

It is not on the evidence of such intermixtures that we ought readily to admit either the high antiquity of the human race, or the recent date of certain lost species of quadrupeds.

Among the various modes in which the bones of animals become preserved, independently of the agency of land-floods and engulphed rivers, I may mention that open fissures often serve as natural pit-falls in which herbivorous animals perish. This may happen the more readily when they are chased by beasts of prey, or when surprised while carelessly browsing on the shrubs which so often overgrow and conceal the edges of fissures.‡

During the excavations recently made near Behat in India, the bones of two deer were found at the bottom

* Desnoyers, Bull. de la Soc. Géol. de France, tom. ii. p. 252.

† Hist. Rom. Epit., lib. iii. c. 10.

‡ Buckland, Reliquiæ Diluvianæ, p. 25.

of an ancient well which had been filled up with alluvial loam. Their horns were broken to pieces, but the jaw bones and other parts of the skeleton remained tolerably perfect. "Their presence," says Captain Cautley, "is easily accounted for, as a great number of these and other animals are constantly lost in galloping over the jungles and among the high grass, by falling into deserted wells." *

Above the village of Selside, near Ingleborough in Yorkshire, a chasm of enormous but unknown depth occurs in the scar-limestone, a member of the carboniferous series. "The chasm," says Professor Sedgwick, "is surrounded by grassy shelving banks, and many animals, tempted towards its brink, have fallen down and perished in it. The approach of cattle is now prevented by a strong lofty wall; but there can be no doubt that, during the last two or three thousand years, great masses of bony breccia must have accumulated in the lower parts of the great fissure, which probably descends through the whole thickness of the scar-limestone, to the depth of perhaps five or six hundred feet." †

When any of these natural pit-falls happen to communicate with lines of subterranean caverns, the bones, earth, and breccia, may sink by their own weight, or be washed into the vaults below.

At the north extremity of the rock of Gibraltar are perpendicular fissures, on the ledges of which a number of hawks nestle and rear their young in the breeding season. They throw down from their nests the bones

* See p. 288., and places cited there.

† Memoir on the Structure of the Lake Mountains of the North of England, &c., read before the Geological Society, Jan. 5. 1831.

of small birds, mice, and other animals on which they feed, and these are gradually united into a breccia of angular fragments of the decomposing limestone with a cement of red earth.

At the pass of Escrinet in France, on the northern escarpment of the Coiron hills, near Aubenas, I have seen a breccia in the act of forming. Small pieces of disintegrating limestone are transported, during heavy rains, by a streamlet, to the foot of the declivity, where land shells are very abundant. The shells and pieces of stone soon become cemented together by stalagmite into a compact mass, and the talus thus formed is in one place fifty feet deep, and five hundred yards wide. So firmly is the lowest portion consolidated, that it is quarried for mill-stones.

Recent stalagmitic limestone of Cuba. — One of the most singular examples of the recent growth of stalagmitic limestone in caves and fissures, is that described by Mr. R. C. Taylor, as observable on the north-east part of the island of Cuba.* The country there is composed of a white marble, in which are numerous cavities, partially filled with a calcareous deposit of a brick red colour. In this red deposit are shells, or often the hollow casts of shells, chiefly referable to eight or nine species of land snails, a few scattered bones of quadrupeds, and, what is still more singular, marine univalve shells, often at the height of many hundred, or even one thousand feet above the sea. The following explanation is given of the gradual increase of this deposit. Land shells of the genera Helix, Cyclostoma, Pupa, and Clausilia, retire into the caves,

* Notes on Geol. of Cuba, from Observations made in 1836, Phil. Mag., July, 1837.

the floors of which are strewed with myriads of their dead and unoccupied shells, at the same time that water infiltered through the mountain throws down carbonate of lime, enveloping the shells, together with fragments of the white limestone which occasionally falls from the roof. Multitudes of bats resort to the caves; and their dung, which is of a bright red colour, (probably derived from the berries on which they feed,) imparts its red hue to the mass. Sometimes also the Hutia, or great Indian rat of the island, dies and leaves its bones in the caves. "At certain seasons the soldier-crabs resort to the sea-shore, and then return from their pilgrimage, each carrying with them, or rather dragging, the shell of some marine univalve for many a weary mile. They may be traced even at the distance of eight or ten miles from the shore, on the summit of mountains 1200 feet high, like the pilgrims of the olden times, each bearing his shell to denote the character and extent of his wanderings." By this means several species of marine testacea of the genera Trochus, Turbo, Littorina, and Monodonta are conveyed into inland caverns, and enter into the composition of the newly formed rock.

CHAPTER XV.

IMBEDDING OF ORGANIC REMAINS IN SUBAQUEOUS DEPOSITS.

Division of the subject — Imbedding of terrestrial animals and plants — Increased specific gravity of wood sunk to great depths in the sea — Drift timber of the Mackenzie in Slave Lake and Polar Sea — Floating trees in the Mississippi — in the Gulf Stream — on the coast of Iceland, Spitzbergen, and Labrador — Submarine forests — Example on coast of Hampshire — Mineralization of plants — Imbedding of the remains of insects — of reptiles — Bones of birds why rare — Imbedding of terrestrial quadrupeds by river-floods — Skeletons in recent shell marl — Imbedding of mammiferous remains in marine strata.

Division of the subject. — HAVING treated of the imbedding of organic remains in deposits formed upon the land, I shall next consider the including of the same in deposits formed under water.

It will be convenient to divide this branch of our subject into three parts; considering, first, the various modes whereby the relics of *terrestrial* species may be buried in subaqueous formations; secondly, the modes whereby animals and plants inhabiting *fresh water* may be so entombed; thirdly, how *marine* species may become preserved in new strata.

The phenomena above enumerated demand a fuller share of attention than those previously examined, since the deposits which originate upon dry land are insignificant in thickness, superficial extent, and dura-

bility, when contrasted with those of subaqueous origin. At the same time, the study of the latter is beset with greater difficulties; for we are here concerned with the results of processes much farther removed from the sphere of ordinary observation. There is, indeed, no circumstance which so seriously impedes the acquisition of just views in our science as an habitual disregard of the important fact, that the reproductive effects of the principal agents of change are confined to another element — to that larger portion of the globe, from which, by our very organization, we are almost entirely excluded.*

Imbedding of Terrestrial Plants.

When a tree falls into a river from the undermining of the banks, or from being washed in by a torrent or flood, it floats on the surface, not because the woody portion is specifically lighter than water, but because it is full of pores containing air. When soaked for a considerable time, the water makes its way into these pores, and the wood becomes *water-logged* and sinks. The time required for this process varies in different woods; but several kinds may be drifted to great distances, sometimes across the ocean, before they lose their buoyancy.

Wood sunk to a great depth in the sea. — If wood be sunk to vast depths in the sea, it may be impregnated with water suddenly. Captain Scoresby informs us, in his Account of the Arctic Regions, that on one occasion a whale, on being harpooned, ran out all the lines in the boat, which it then dragged under water, to the depth of several thousand feet, the men having

* See Book I., ch. v.

just time to escape to a piece of ice. When the fish returned to the surface "to blow," it was struck a second time, and soon afterwards killed. The moment it expired it began to sink,—an unusual circumstance, which was found to be caused by the weight of the sunken boat, which still remained attached to it. By means of harpoons and ropes the fish was prevented from sinking, until it was released from the weight by connecting a rope to the lines of the attached boat, which was no sooner done than the fish rose again to the surface. The sunken boat was then hauled up with great labour; for so heavy was it, that although before the accident it would have been buoyant when full of water, yet it now required a boat at each end to keep it from sinking. "When it was hoisted into the ship, the paint came off the wood in large sheets; and the planks, which were of wainscot, were as completely soaked in every pore as if they had lain at the bottom of the sea since the flood! A wooden apparatus that accompanied the boat in its progress through the deep, consisting chiefly of a piece of thick deal, about fifteen inches square, happened to fall overboard, and, though it originally consisted of the lightest fir, sank in the water like a stone. The boat was rendered useless: even the wood of which it was built, on being offered to the cook for fuel, was tried and rejected as incombustible."*

Captain Scoresby found that, by sinking pieces of fir, elm, ash, &c., to the depth of four thousand and sometimes six thousand feet, they became impregnated with sea-water, and when drawn up again, after immersion, for an hour, would no longer float. The

* Account of the Arctic Regions, vol. ii. p. 193.

effect of this impregnation was to increase the dimensions as well as the specific gravity of the wood, every solid inch having increased one-twentieth in size and twenty-one twenty-fifths in weight.*

Drift-wood of the Mackenzie River. — When timber is drifted down by a river, it is often arrested by lakes: and, becoming water-logged, it may sink and be imbedded in lacustrine strata, if any be there forming: sometimes a portion floats on till it reaches the sea. In the course of the Mackenzie River we have an example of vast accumulations of vegetable matter now in progress under both these circumstances.

In Slave Lake in particular, which vies in dimensions with some of the great fresh-water seas of Canada, the quantity of drift-timber brought down annually is enormous. "As the trees," says Dr. Richardson, "retain their roots, which are often loaded with earth and stones, they readily sink, especially when water-soaked; and, accumulating in the eddies, form shoals, which ultimately augment into islands. A thicket of small willows covers the new-formed island as soon as it appears above water, and their fibrous roots serve to bind the whole firmly together. Sections of these islands are annually made by the river, assisted by the frost; and it is interesting to study the diversity of appearances they present, according to their different ages. The trunks of the trees gradually decay until they are converted into a blackish brown substance resembling peat, but which still retains more or of less the fibrous structure of the wood; and layers of this often alternate with layers of clay and sand, the whole being penetrated, to the depth of four or

* Account of the Arctic Regions, vol. ii. p. 202.

five yards or more, by the long fibrous roots of the willows. A deposition of this kind, with the aid of a little infiltration of bituminous matter, would produce an excellent imitation of coal, with vegetable impressions of the willow-roots. What appeared most remarkable was the horizontal slaty structure that the old alluvial banks presented, or the *regular curve* that the strata assumed from unequal subsidence.

"It was in the rivers only that we could observe sections of these deposits; but the same operation goes on on a much more magnificent scale in the lakes. A shoal of many miles in extent is formed on the south side of Athabasca Lake, by the drift-timber and vegetable debris brought down by the Elk River; and the Slave Lake itself must in process of time be filled up by the matters daily conveyed into it from Slave River. Vast quantities of drift-timber are buried under the sand at the mouth of the river, and enormous piles of it are accumulated on the shores of every part of the lake." *

The banks of the Mackenzie display almost every where horizontal beds of wood coal, alternating with bituminous clay, gravel, sand, and friable sandstone; sections, in short, of such deposits as are now evidently forming at the bottom of the lakes which it traverses.

Notwithstanding the vast forests intercepted by the lakes, a still greater mass of drift-wood is found where the Mackenzie reaches the sea, in a latitude where no wood grows at present except a few stunted willows. At the mouths of the river the alluvial matter has formed a barrier of islands and shoals, where we

* Dr. Richardson's Geognost. Obs. on Capt. Franklin's Polar Expedition.

may expect a great formation of coal at some distant period.

The abundance of floating timber on the Mackenzie is owing, as Dr. Richardson informs me, to the direction and to the length of the course of this river, which runs from south to north, so that the sources of the stream lie in much warmer latitudes than its mouths. In the country, therefore, where the sources are situated, the frost breaks up at an earlier season, while yet the waters in the lower part of its course are ice-bound. Hence the current of water, rushing down northward, reaches a point where the thaw has not begun, and, finding the channel of the river blocked up with ice, it overflows the banks, sweeping through forests of pines, and carrying away thousands of uprooted trees.

Drift-wood of the Mississippi.—I have already observed that the navigation of the Mississippi is much impeded by trunks of trees half sunk in the river.* On reaching the Gulf of Mexico many of them subside, and are imbedded in the new strata which form the delta, but many of them float on and enter the Gulf stream. "Tropical plants (says M. Constant Prevost) are taken up by this great current, and carried in a northerly direction till they reach the shores of Iceland and Spitzbergen uninjured. A great portion of them are doubtless arrested on their passage, and probably always in the same inlets, or the same spots on the bottom of the ocean; in fact, wherever an eddy or calm determines their distribution, which, in this single example, extends over a space comprehended between the equator and the eightieth degree

* Book II. chap. ii.

of latitude — an immense space, six times more considerable than that occupied by all Europe, and thirty times larger than France. The drifting of various substances, though regular, is not continual: it takes place by intermittence after great inundations of rivers, and in the intervals the waters may carry sand only or mud, or each of these alternately, to the same localities." *

Drift-timber on coasts of Iceland, Spitzbergen, &c. — The ancient forests of Iceland, observes Malte-Brun, have been improvidently exhausted; but, although the Icelander can obtain no timber from the land, he is supplied with it abundantly by the ocean. An immense quantity of thick trunks of pines, firs, and other trees, are thrown upon the northern coast of the island, especially upon North Cape and Cape Langaness, and are then carried by the waves along these two promontories to other parts of the coast, so as to afford sufficiency of wood for fuel and for constructing boats. Timber is also carried to the shores of Labrador and Greenland; and Crantz assures us that the masses of floating wood thrown by the waves upon the island of John de Mayen often equal the whole of that island in extent.†

In a similar manner the bays of Spitzbergen are filled with drift-wood, which accumulates also upon those parts of the coast of Siberia that are exposed to the east, consisting of larch trees, pines, Siberian cedars, firs, and Fernambucco and Campeachy woods. These trunks appear to have been swept away by the

* Mém. de la Soc. d'Hist. Nat. de Paris, vol. iv. p. 84.

† Malte-Brun, Geog., vol. v. part i. p. 112. — Crantz, Hist. of Greenland, tome i. pp. 50—54.

great rivers of Asia and America. Some of them are brought from the Gulf of Mexico, by the Bahama stream; while others are hurried forward by the current which, to the north of Siberia, constantly sets in from east to west. Some of these trees have been deprived of their bark by friction, but are in such a state of preservation as to form excellent building timber.* Parts of the branches and almost all the roots remain fixed to the pines which have been drifted into the North Sea, into latitudes too cold for the growth of such timber, but the trunks are usually barked.

The leaves and lighter parts of plants are seldom carried out to sea, in any part of the globe, except during tropical hurricanes among islands, and during the agitations of the atmosphere which sometimes accompany earthquakes and volcanic eruptions.†

Comparative number of living and fossilized species of plants.— It will appear from these observations that, although the remains of terrestrial vegetation, borne down by aqueous causes from the land, are chiefly deposited at the bottom of lakes or at the mouths of rivers; yet a considerable quantity is drifted about in all directions by currents, and may become imbedded in any *marine* formation, or may sink down, when water-logged, to the bottom of unfathomable abysses, and there accumulate without intermixture of other substances.

It may be asked whether we have any data for inferring that the remains of a considerable proportion of the existing species of plants will be permanently pre-

* Olafsen, Voyage to Iceland, tome i. Malte-Brun's Geog. vol. v. part i. p. 112.

† De la Beche, Geol. Manual, p. 477.

served, so as to be hereafter recognizable, supposing the strata now in progress to be at some future period upraised? To this inquiry it may be answered, that there are no reasons for expecting that more than a small number of the plants now flourishing in the globe will become fossilized; since the entire habitations of a great number of them are remote from lakes and seas, and even where they grow near to large bodies of water, the circumstances are quite accidental and partial which favour the imbedding and conservation of vegetable remains. Suppose, for example, that the species of plants inhabiting the hydrographical basin of the Rhine, or that region, extending from the Alps to the sea, which is watered by the Rhine and its numerous tributaries, to be about 2500 in number, exclusive of the cryptogamic class. This estimate is by no means exaggerated; yet if a geologist could explore the deposits which have resulted from the sediment of the Rhine in the lake of Constance, and off the coast of Holland, he might scarcely be able to obtain from the recent strata the leaves, wood, and seeds of *fifty* species in such a state of preservation as to enable a botanist to determine their specific characters with certainty.

Those naturalists, therefore, who infer that the ancient flora of the globe was, at certain periods, less varied than now, merely because they have as yet discovered only a few hundred fossil species of a particular epoch, while they can enumerate more than fifty thousand living ones, are reasoning on a false basis, and their standard of comparison is not the same in the two cases.

Submarine forest on coast of Hants.—We have already seen that the submarine position of several

forests, or the remains of trees standing in a vertical position on the British shores has been due, in some instances, to the subsidence of land.* There are some cases which require a different explanation. The Honourable Charles Harris discovered, in 1831, evident traces of a fir-wood, beneath the mean level of the sea, at Bournmouth, in Hampshire, the formation having been laid open during a low spring tide. It is composed of peat and wood, and is situated between the beach and a bar of sand about 200 yards off, and extends fifty yards along the shore. It also lies in the direct line of the Bournmouth Valley, from the termination of which it is separated by 200 yards of shingle and drift-sand. Down the valley flows a large brook, traversing near its mouth a considerable tract of rough, boggy, and heathy ground, which produces a few birch trees, and a great abundance of the *Myrica Gale*. Seventy-six rings of annual growth were counted in a transverse section of one of the buried fir trees, which was fourteen inches in diameter. Besides the stumps and roots of fir, pieces of alder and birch are found in the peat; and it is a curious fact, that a part of many of the trees has been converted into iron pyrites. The peat rests on pebbly strata, precisely similar to the sand and pebbles occurring on the adjoining heaths.

As the sea is encroaching on this shore, we may suppose that at some former period the Bourne Valley extended farther, and that its extremity consisted, as at present, of boggy ground, partly clothed with fir-trees. The bog rested on that bed of pebbles which we now see below the peat; and the sea, in its progressive encroachments, eventually laid bare, at low

* See Vol. II. pp. 46. and 80.

water, the sandy foundations; upon which a stream of fresh water rushing through the sand at the fall of the tides, carried out loose sand with it. The superstratum of vegetable matter being matted and bound together by the roots of trees, remained; but being undermined, sank down below the level of the sea, and then the waves washed sand and shingle over it. In support of this hypothesis, it may be observed, that small streams of fresh water often pass under the sands of the sea-beach, so that they may be crossed dry-shod; and the water is seen, at the point where it issues, to carry out sand and even pebbles.

Mineralization of plants.— Although the botanist and chemist have as yet been unable to explain fully the manner in which wood becomes petrified, it is nevertheless ascertained that, under favourable circumstances, the lapidifying process is now continually going on. A piece of wood was lately procured by Mr. Stokes, from an ancient Roman aqueduct in Westphalia, in which some portions were converted into spindle-shaped bodies, consisting of carbonate of lime, while the rest of the wood remained in a comparatively unchanged state.* It appears that in some cases the most perishable, in others the most durable, portions of plants are preserved, variations which doubtless depend on the time when the mineral matter was supplied. If introduced immediately, on the first commencement of decomposition, then the most destructible parts are lapidified, while the more durable do not waste away till afterwards, when the supply has failed, and so never become petrified. The converse of these circumstances gives rise to exactly opposite results.

* Geol. Trans., second series, vol. v. p. 212.

Professor Göppert, of Breslau, has instituted a series of curious experiments, in which he has succeeded in producing some very remarkable imitations of fossil petrifactions. He placed recent ferns between soft layers of clay, dried these in the shade, and then slowly and gradually heated them, till they were red hot. The result was the production of so perfect a counterpart of fossil plants as might have deceived an experienced geologist. According to the different degrees of heat applied, the plants were obtained in a brown or perfectly carbonized condition; and sometimes, but more rarely, they were in a black shining state, adhering closely to the layer of clay. If the red heat was sustained until all the organic matter was burnt up, only an impression of the plant remained.

The same chemist steeped plants in a moderately strong solution of sulphate of iron, and left them immersed in it for several days, until they were thoroughly soaked in the liquid. They were then dried, and kept heated until they would no longer shrink in volume, and until every trace of organic matter had disappeared. On cooling them he found that the oxide formed by this process had taken the form of the plants. A variety of other experiments were made by steeping animal and vegetable substances in siliceous, calcareous, and metallic solutions, and all tended to prove that the mineralization of organic bodies can be carried much farther in a short time than had been previously supposed.*

* Göppert, Poggendorff's Annalen der Physik und Chemie, vol. xxxviii. part iv., Leipsic. 1836.

Imbedding of the Remains of Insects.

I have observed the elytra and other parts of beetles in a band of fissile clay, separating two beds of recent shell-marl, in the Loch of Kinnordy in Forfarshire. Amongst these, Mr. Curtis recognized *Elater lineatus* and *Atopa cervina*, species still living in Scotland. These, as well as other remains which accompanied them, appear to belong to terrestrial, not aquatic, species, and must have been carried down in muddy water during an inundation. In the lacustrine peat of the same locality, the elytra of beetles are not uncommon; but in the deposits of drained lakes generally, and in the silt of our estuaries, the relics of this class of the animal kingdom are rare. In the blue clay of very modern origin of Lewes levels, Mr. Mantell has found the Indusia, or cases of the larvæ of Phryganea, in abundance, with minute shells belonging to the genera Planorbis, Limnea, &c., adhering to them.*

When speaking of the migrations of insects, I pointed out that an immense number are floated into lakes and seas by rivers, or blown by winds far from the land; but they are so buoyant that we can only suppose them, under very peculiar circumstances, to sink to the bottom before they are either devoured by insectivorous animals or decomposed.

Remains of Reptiles.

As the bodies of several crocodiles were found in the mud brought down to the sea by the river inundation which attended an earthquake in Java, in the year 1699, we may imagine that extraordinary floods of

* Trans. Geol. Soc., vol. iii. part i. p. 201. second series.

mud may stifle many individuals of the shoals of alligators and other reptiles which frequent lakes and the deltas of rivers in tropical climates. Thousands of frogs were found leaping about among the wreck, carried into the sea by the inundations in Morayshire, in 1829;* and it is evident that whenever a sea-cliff is undermined, or land is swept by other violent causes into the sea, land reptiles may be carried in.

Remains of Birds.

We might have anticipated that the imbedding of the remains of birds in new strata would be of very rare occurrence, for their powers of flight insure them against perishing by numerous casualties to which quadrupeds are exposed during floods; and if they chance to be drowned, or to die when swimming on the water, it will scarcely ever happen that they will be submerged so as to become preserved in sedimentary deposits. In consequence of the hollow tubular structure of their bones and the quantity of their feathers, they are extremely light in proportion to their volume; so that when first killed they do not sink to the bottom like quadrupeds, but float on the surface until the carcass either rots away or is devoured by predaceous animals. To these causes we may ascribe the absence of any vestige of the bones of birds in the recent marl formations of Scotland; although these lakes, until the moment when they were artificially drained, were frequented by a great abundance of water-fowl.

* Sir T. D. Lauder's Account, second edition, p. 312.

Imbedding of Terrestrial Quadrupeds.

River inundations recur in most climates at very irregular intervals, and expend their fury on those rich alluvial plains, where herds of herbivorous quadrupeds congregate together. These animals are often surprised; and, being unable to stem the current, are hurried along, until they are drowned, when they sink at first immediately to the bottom. Here their bodies are drifted along, together with sediment, into lakes or seas, and may then be covered by a mass of mud, sand, and pebbles, thrown down upon them. If there be no sediment superimposed, the gases generated by putrefaction usually cause the bodies to rise again to the surface about the ninth, or at latest the fourteenth day. The pressure of a thin covering of mud would not be sufficient to retain them at the bottom; for we see the putrid carcasses of dogs and cats, even in rivers, floating with considerable weights attached to them, and in sea-water they would be still more buoyant.

Where the body is so buried in drift-sand, or mud accumulated upon it, as never to rise again, the skeleton may be preserved entire; but if it comes again to the surface while in the process of putrefaction, the bones commonly fall piecemeal from the floating carcass, and may in that case be scattered at random over the bottom of the lake, estuary, or sea; so that a jaw may afterwards be found in one place, a rib in another, a humerus in a third — all included, perhaps, in a matrix of fine materials, where there may be evidence of very slight transporting power in the current, or even of none, but simply of some chemical precipitate.

A large number of the bodies of drowned animals, if they float into the sea or a lake, especially in hot climates, are instantly devoured by sharks, alligators, and other carnivorous beasts, which may have power to digest even the bones; but during extraordinary floods, when the greatest number of land animals are destroyed, the waters are commonly so turbid, especially at the bottom of the channel, that even aquatic species are compelled to escape into some retreat where there is clearer water, lest they should be stifled. For this reason, as well as the rapidity of sedimentary deposition at such seasons, the probability of carcasses becoming permanently imbedded is considerable.

Flood in the Solway Firth, 1794.—One of the most memorable floods of modern date, in our island, is that which visited part of the southern borders of Scotland, on the 24th of January, 1794, and which spread particular devastation over the country adjoining the Solway Firth.

We learn from the account of Captain Napier, that the heavy rains had swollen every stream which entered the Firth of Solway; so that the inundation not only carried away a great number of cattle and sheep, but many of the herdsmen and shepherds, washing down their bodies into the estuary. After the storm, when the flood subsided, an extraordinary spectacle was seen on a large sand-bank, called "the beds of Esk," where there is a meeting of the tidal waters, and where heavy bodies are usually left stranded after great floods. On this single bank were found collected together the bodies of 9 black cattle, 3 horses, 1840 sheep, 45 dogs, 180 hares, besides a great number of

smaller animals, and, mingled with the rest, the corpses of two men and one woman.*

Floods in Scotland, 1829. — In those more recent floods in Scotland, in August, 1829, whereby a fertile district on the east coast became a scene of dreadful desolation, a vast number of animals and plants were washed from the land, and found scattered about after the storm, around the mouths of the principal rivers. An eye-witness thus describes the scene which presented itself at the mouth of the Spey, in Morayshire: — "For several miles along the beach crowds were employed in endeavouring to save the wood and other wreck with which the heavy-rolling tide was loaded; whilst the margin of the sea was strewed with the carcasses of domestic animals, and with millions of dead hares and rabbits." †

Savannahs of South America. — We are informed by Humboldt, that during the periodical swellings of the large rivers in South America great numbers of quadrupeds are annually drowned. Of the wild horses, for example, which graze in immense troops in the savannahs, thousands are said to perish when the river Apure, a tributary of the Orinoco, is swollen, before they have time to reach the rising ground of the Llanos. The mares, during the season of high water, may be seen, followed by their colts, swimming about and feeding on the grass, of which the top alone waves above the waters. In this state they are pursued by crocodiles; and their thighs frequently bear the prints of the teeth of these carnivorous reptiles. "Such is the pliability," observes the celebrated traveller, "of

* Treatise on Practical Store Farming, p. 25.

† Sir T. D. Lauder's Floods in Morayshire, 1829, p. 312., second ed.; and see above, Book II. chap. i.

the organizatian of the animals which man has subjected to his sway, that horses, cows, and other species of European origin, lead, for a time, an amphibious life, surrounded by crocodiles, water-serpents, and manatees. When the rivers return again into their beds, they roam in the savannah, which is then spread over with a fine odoriferous grass, and enjoy, as in their native climate, the renewed vegetation of spring."*

Floods of the Parana.—The great number of animals which are drowned in seasons of drought in the tributaries of the Plata, was before mentioned. Sir W. Parish states, that the Parana flowing from the mountains of Brazil to the estuary of the Plata, is liable to great floods, and during one of these, in the year 1812, vast quantities of cattle were carried away, "and when the waters began to subside, and the islands which they had covered became again visible, the whole atmosphere for a time was poisoned by the effluvia from the innumerable carcasses of skunks, capiguaras, tigers, and other wild beasts which had been drowned."†

Floods of the Ganges.—We find it continually stated, by those who describe the Ganges and Burrampooter, that these rivers carry before them, during the flood season, not only floats of reeds and timber, but dead bodies of men, deer, and oxen.‡

In Java, 1699.—I have already referred to the effects of a flood which attended an earthquake in Java in 1699, when the turbid waters of the Batavian river destroyed all the fish except the carp; and when

* Humboldt's Pers. Nar., vol. iv. pp. 394—396.

† Buenos Ayres and La Plata, p. 187.

‡ Malte-Brun, Geog., vol. iii. p. 22.

drowned buffaloes, tigers, rhinoceroses, deer, apes, and other wild beasts, were brought down to the sea-coast by the current, with several crocodiles which had been stifled in the mud.*

On the western side of the same island, in the territory of Galongoon, in the Regencies, a more recent volcanic eruption (that of 1822, before described†) was attended by a flood, during which the river Tandoi bore down hundreds of carcasses of rhinoceroses and buffaloes, and swept away more than one hundred men and women from a multitude assembled on its banks to celebrate a festival. Whether the bodies reached the sea, or were deposited, with drift matter, in some of the large intervening alluvial plains, we are not informed.‡

Sumatra. — "On the coast of Orissa," says Heynes, "I have seen tigers and whole herds of black cattle carried along by what are called freshes, and trees of immense size."§

In Virginia, 1771. — I might enumerate a great number of local deluges that have swept through the fertile lands bordering on large rivers, especially in tropical countries, but I should surpass the limits assigned to this work. I may observe, however, that the destruction of the islands, in rivers, is often attended with great loss of lives. Thus when the principal river in Virginia rose, in 1771, to the height of twenty-five feet above its ordinary level, it swept entirely away Elk Island, on which were seven hundred head of

* See Vol. II. p. 376. † Vol. II. p. 263.

‡ This account I had from Mr. Baumhauer, Director-General of Finances in Java.

§ Tracts on India, p. 397.

quadrupeds, — horses, oxen, sheep, and hogs, — and nearly one hundred houses.*

The reader will gather, from what was before said respecting the deposition of sediment by aqueous causes, that the greater number of the remains of quadrupeds drifted away by rivers must be intercepted by lakes before they reach the sea, or buried in freshwater formations near the mouths of rivers. If they are carried still farther, the probabilities are increased of their rising to the surface in a state of putrefaction, and, in that case, of being there devoured by aquatic beasts of prey, or of subsiding into some spots whither no sediment is conveyed, and, consequently, where every vestige of them will, in the course of time, disappear.

Skeletons of animals in recent shell-marl, Scotland.— In some instances, the skeletons of quadrupeds are met with abundantly in recent shell-marls in Scotland, where we cannot suppose them to have been imbedded by the action of rivers or floods. They all belong to species which now inhabit, or are known to have been indigenous in Scotland. The remains of several hundred skeletons have been procured within the last century, from five or six small lakes in Forfarshire, where shell-marl has been worked. Those of the stag (*Cervus elaphus*) are most numerous; and if the others be arranged in the order of their relative abundance, they will follow nearly thus — the ox, the boar, the horse, the sheep, the dog, the hare, the fox, the wolf, and the cat. The beaver seems extremely rare; but it has been found in the shell-marl of Loch Marlie, in Perthshire, and in the parish of Edrom, in Berwickshire.

* Scots Mag., vol. xxxiii.

In the greater part of these lake-deposits there are no signs of floods; and the expanse of water was originally so confined, that the smallest of the above-mentioned quadrupeds could have crossed, by swimming, from one shore to the other. Deer, and such species as take readily to the water, may often have been mired in trying to land, where the bottom was soft and quaggy, and in their efforts to escape may have plunged deeper into the marly bottom. Some individuals, I suspect, of different species, have fallen in when crossing the frozen surface in winter; for nothing can be more treacherous than the ice when covered with snow, in consequence of the springs, which are numerous, and which, retaining always an equal temperature, cause the ice, in certain spots, to be extremely thin, while in every other part of the lake it is strong enough to bear the heaviest weights.

Mammiferous remains in marine strata. — As the bones of mammalia are often so abundantly preserved in peat, and such lakes as have just been described, the encroachments of a sea upon a coast may sometimes throw down the imbedded skeletons, so that they may be carried away by tides and currents, and entombed in subaqueous formations. Some of the smaller quadrupeds, also, which burrow in the ground, as well as reptiles and every species of plant, are liable to be cast down into the waves by this cause, which must not be overlooked, although probably of comparatively small importance amongst the numerous agents whereby terrestrial organic remains are included in submarine strata.

During the great earthquake of Conception in 1835, some cattle, which were standing on the steep sides of

the island of Quiriquina, were rolled by the shock into the sea, while on a low island at the head of the Bay of Conception seventy animals were washed off by a great wave and drowned.*

* Darwin's Journal, p. 372.

CHAPTER XVI.

IMBEDDING OF THE REMAINS OF MAN AND HIS WORKS IN SUBAQUEOUS STRATA.

Drifting of human bodies to the sea by river inundations — Destruction of bridges and houses — Loss of lives by shipwreck — How human corpses may be preserved in recent deposits — Number of wrecked vessels — Fossil skeletons of men — Fossil canoes, ships, and works of art — Chemical changes which metallic articles have undergone after long submergence — Imbedding of cities and forests in subaqueous strata by subsidence — Earthquake of Cutch in 1819 — Berkley's arguments for the recent date of the creation of man — Concluding remarks.

I SHALL now proceed to inquire in what manner the mortal remains of man and the works of his hands may be permanently preserved in subaqueous strata. Of the many hundred million human beings which perish in the course of every century on the land, every vestige is usually destroyed in the course of a few thousand years; but of the smaller number that perish in the waters, a considerable proportion must frequently be entombed under such circumstances, that parts of them may endure throughout entire geological epochs.

The bodies of men, together with those of the inferior animals, are occasionally washed down during river inundations into seas and lakes.* Belzoni wit-

* See pp. 323. 325.

nessed a flood on the Nile in September, 1818, where, although the river rose only three feet and a half above its ordinary level, several villages, with some hundreds of men, women, and children, were swept away.* It was before mentioned that a rise of six feet of water in the Ganges, in 1763, was attended with a much greater loss of lives.†

In the year 1771, when the inundations in the north of England appear to have equalled the recent floods in Morayshire, a great number of houses and their inhabitants were swept away by the rivers Tyne, Can, Wear, Tees, and Greta; and no less than twenty-one bridges were destroyed in the courses of these rivers. At the village of Bywell the flood tore the dead bodies and coffins out of the churchyard, and bore them away, together with many of the living inhabitants. During the same tempest an immense number of cattle, horses, and sheep, were also transported to the sea, while the whole coast was covered with the wreck of ships. Four centuries before (in 1338), the same district had been visited by a similar continuance of heavy rains followed by disastrous floods, and it is not improbable that these catastrophes may recur periodically, though after uncertain intervals. As the population increases, and buildings and bridges are multiplied, we must expect the loss of lives and property to augment.‡

Fossilization of human bodies in the bed of the sea. — If to the hundreds of human bodies committed to the deep in the way of ordinary burial we add those of individuals lost by shipwrecks, we shall find that, in

* Narrative of Discovery in Egypt, &c., London, 1820.

† Vol. II. p. 7.

‡ Scots Mag., vol. xxxiii., 1771.

the course of a single year, a great number of human remains are consigned to the subaqueous regions. I shall hereafter advert to a calculation by which it appears that more than five hundred *British* vessels alone, averaging each a burthen of about 120 tons, are wrecked, and sink to the bottom, *annually*. Of these the crews for the most part escape, although it sometimes happens that all perish. In one great naval action several thousand individuals sometimes share a watery grave.

Many of these corpses are instantly devoured by predaceous fish, sometimes before they reach the bottom; still more frequently when they rise again to the surface, and float in a state of putrefaction. Many decompose on the floor of the ocean, where no sediment is thrown down upon them; but if they fall upon a reef where corals and shells are becoming agglutinated into a solid rock, or subside where the delta of a river is advancing, they may be preserved for an incalculable series of ages.

Often at the distance of a few hundred feet from a coral reef, where wrecks are not unfrequent, there are no soundings at the depth of many hundred fathoms. Canoes, merchant vessels, and ships of war may have sunk and have been enveloped, in such situations, in calcareous sand and breccia, detached by the breakers from the summit of a submarine mountain. Should a volcanic eruption happen to cover such remains with ashes and sand, and a current of lava be afterwards poured over them, the ships and human skeletons might remain uninjured beneath the superincumbent mass, like the houses and works of art in the subterranean cities of Campania. Already many human remains may have been thus preserved beneath form-

ations more than a thousand feet in thickness; for, in some volcanic archipelagos, a period of thirty or forty centuries might well be supposed sufficient for such an accumulation.

It was stated, that at the distance of about forty miles from the base of the delta of the Ganges, there is a circular space about fifteen miles in diameter where soundings of from 600 to 800 feet sometimes fail to reach the bottom.* As during the flood season the quantity of mud and sand poured by the great rivers into the Bay of Bengal is so great that the sea only recovers its transparency at the distance of sixty miles from the coast, this depression must be gradually shoaling, especially as during the monsoons, the sea loaded with mud and sand, is beaten back in that direction towards the delta. Now, if a ship or human body sink down to the bottom in such a spot, it is by no means improbable that it may become buried under a depth of a thousand feet of sediment in the same number of years.

Even on that part of the floor of the ocean to which no accession of drift matter is carried (a part which probably constitutes, at any given period, by far the larger proportion of the whole submarine area), there are circumstances accompanying a wreck which favour the conservation of skeletons. For when the vessel fills suddenly with water, especially in the night, many persons are drowned between decks and in their cabins, so that their bodies are prevented from rising again to the surface. The vessel often strikes upon an uneven bottom, and is overturned; in which case the ballast, consisting of sand, shingle, and rock, or the cargo,

* Vol. II. p. 3.

frequently composed of heavy and durable materials, may be thrown down upon the carcasses. In the case of ships of war, cannon, shot, and other warlike stores, may press down with their weight the timbers of the vessel as they decay, and beneath these and the metallic substances the bones of man may be preserved.

Number of wrecked vessels.—When we reflect on the number of curious monuments consigned to the bed of the ocean in the course of every naval war from the earliest times, our conceptions are greatly raised respecting the multiplicity of lasting memorials which man is leaving of his labours. During our last great struggle with France, thirty-two of our ships of the line went to the bottom in the space of twenty-two years, besides seven 50-gun ships, eighty-six frigates, and a multitude of smaller vessels. The navies of the other European powers, France, Holland, Spain, and Denmark, were almost annihilated during the same period, so that the aggregate of their losses must have many times exceeded that of Great Britain. In every one of these ships were batteries of cannon constructed of iron or brass, whereof a great number had the dates and places of their manufacture inscribed upon them in letters cast in metal. In each there were coins of copper, silver, and often many of gold, capable of serving as valuable historical monuments; in each were an infinite variety of instruments of the arts of war and peace; many formed of materials, such as glass and earthenware, capable of lasting for indefinite ages when once removed from the mechanical action of the waves, and buried under a mass of matter which may exclude the corroding action of sea-water. The quantity moreover of timber which is conveyed from the land to the bed of the sea by the sinking of

ships of a large size is enormous, for it is computed that 2000 tons of wood are required for the building of one 74-gun ship; and reckoning fifty oaks of 100 years growth to the acre, it would require forty acres of oak forest to build one of these vessels.*

It would be an error to imagine that the fury of war is more conducive than the peaceful spirit of commercial enterprise to the accumulation of wrecked vessels in the bed of the sea. From an examination of Lloyd's lists, from the year 1793 to the commencement of 1829, Capt. W. H. Smyth ascertained that the number of *British vessels* alone lost during that period amounted on an average to no less than one and a half *daily;* an extent of loss which would hardly have been anticipated, although we learn from Moreau's tables that the number of merchant vessels employed at one time, in the navigation of England and Scotland, amounts to about twenty thousand, having one with another a mean burthen of 120 tons.† My friend, Mr. J. L. Prevost also informs me that on inspecting Lloyd's lists for the years 1829, 1830, and 1831, he finds that no less than 1953 vessels were lost in those three years, their average tonnage being about 150 tons, or in all nearly 300,000 tons, being at the enormous rate of 100,000 tons annually of the merchant vessels of one nation only. This increased loss arises, I presume, from increasing activity in commerce.

Out of 551 ships of the royal navy lost to the country during the period above mentioned, only 160 were taken or destroyed by the enemy, the rest having either stranded or foundered, or having been burnt by accident; a striking proof that the dangers of our

* Quart. Journ. of Agricult. No. ix. p. 433.

† Cæsar Moreau's Tables of the Navigation of Great Britain

naval warfare, however great, may be far exceeded by the storm, the shoal, the lee-shore, and all the other perils of the deep.*

Durable nature of many of their contents.— Millions of silver dollars and other coins have been sometimes submerged in a single ship, and on these, when they happen to be enveloped in a matrix capable of protecting them from chemical changes, much information of historical interest will remain inscribed, and endure for periods as indefinite as have the delicate markings of zoophytes or lapidified plants in some of the ancient secondary rocks. In almost every large ship, moreover, there are some precious stones set in seals, and other articles of use and ornament composed of the hardest substances in nature, on which letters and various images are carved — engravings which they may retain when included in subaqueous strata, as long as a crystal preserves its natural form.

It was, therefore, a splendid boast, that the deeds of the English chivalry at Agincourt made Henry's chronicle

> ——— as rich with praise
> As is the ooze and bottom of the deep
> With sunken wreck and sumless treasuries;

for it is probable that a greater number of monuments of the skill and industry of man will, in the course of ages, be collected together in the bed of the ocean, than will exist at any one time on the surface of the continents.

If our species be of as recent a date as is generally supposed, it will be vain to seek for the remains of man

* I give these results on the authority of Capt. W. H. Smyth, R. N.

and the works of his hands imbedded in submarine strata, except in those regions where violent earthquakes are frequent, and the alterations of relative level so great, that the bed of the sea may have been converted into land within the historical era. We need not despair, however, of the discovery of such monuments, when those regions which have been peopled by man from the earliest ages, and which are at the same time the principal theatres of volcanic action, shall be examined by the joint skill of the antiquary and geologist.

Power of human remains to resist decay.— There can be no doubt that human remains are as capable of resisting decay as are the harder parts of the inferior animals; and I have already cited the remark of Cuvier, that "in ancient fields of battle the bones of men have suffered as little decomposition as those of horses which were buried in the same grave." * In the delta of the Ganges bones of men have been found in digging a well at the depth of ninety-feet; † but as that river frequently shifts its course and fills up its ancient channels, we are not called upon to suppose that these bodies are of extremely high antiquity, or that they were buried when that part of the surrounding delta where they occur was first gained from the sea.

Fossil skeletons of men.— Several skeletons of men, more or less mutilated, have been found in the West Indies, on the north-west coast of the main-land of Guadaloupe, in a kind of rock which is known to be forming daily, and which consists of minute fragments of shells and corals, incrusted with a calcareous cement

* Vol. I. p. 250. † Von Hoff, vol. i. p. 379.

resembling travertin, by which also the different grains are bound together. The lens show that some of the fragments of coral composing this stone still retain the same red colour which is seen in the reefs of living coral which surround the island. The shells belong to species of the neighbouring sea intermixed with some terrestrial kinds which now live on the island, and among them is the *Bulimus Guadaloupensis* of Férussac. The human skeletons still retain some of their animal matter, and all their phosphate of lime. One of them, of which the head is wanting, may now be seen in the British Museum, and another in the Royal Cabinet at Paris. According to Mr. Kōnig, the rock in which the former is inclosed is harder under the mason's saw and chisel than statuary marble. It is described as forming a kind of glacis, probably an indurated beach, which slants from the steep cliffs of the island to the sea, and is nearly all submerged at high tide.

Similar formations are in progress in the whole of the West Indian archipelago, and they have greatly extended the plain of Cayes in St. Domingo, where fragments of vases and other human works have been found at a depth of twenty feet. In digging wells also near Catania, in Sicily, tools have been discovered in a rock somewhat similar.

Buried ships, canoes, and works of art.—When a vessel is stranded in shallow water, it usually becomes the nucleus of a sand-bank, as has been exemplified in several of our harbours, and this circumstance tends greatly to its preservation. Between the years 1780 and 1790 a vessel from Purbeck, laden with three hundred tons of stone, struck on a shoal off the entrance of Poole harbour and foundered; the crew were

saved, but the vessel and cargo remain to this day at the bottom. Since that period the shoal at the entrance of the harbour has so extended itself in a westerly direction towards Peveril Point in Purbeck, that the navigable channel is thrown a mile nearer that point.* The cause is obvious; the tidal current deposits the sediment with which it is charged around any object which checks its velocity. Matter also drifted along the bottom is arrested by any obstacle, and accumulates round it, just as the African sand-winds, before described, raise a small hillock over the carcass of every dead camel exposed on the surface of the desert.

I before alluded to an ancient Dutch vessel, discovered in the deserted channel of the river Rother, in Sussex, of which the oak wood was much blackened, but its texture unchanged.† The interior was filled with fluviatile silt, as was also the case in regard to a vessel discovered in a former bed of the Mersey, and another disinterred where the St. Katherine Docks are excavated in the alluvial plain of the Thames. In like manner many ships have been found preserved entire in modern strata, formed by the silting up of estuaries along the southern shores of the Baltic, especially in Pomerania. Between Bromberg and Nakel, for example, a vessel and two anchors in a very perfect state were dug up far from the sea.‡

Several vessels have been lately detected half buried in the delta of the Indus, in the numerous deserted branches of that river, far from where the stream now flows. One of these, found near Vikkar

* This account I received from the Honourable Chas. Harris.

† Vol. II. p. 70.

‡ Von Hoff, vol. i. p. 368.

in Sinde, was 400 tons in burthen, old fashioned, and pierced for fourteen guns, and in a region where it had been matter of dispute whether the Indus had ever been navigable by large vessels.*

At the mouth of a river in Nova Scotia, a schooner of thirty-two tons, laden with live stock, was lying with her side to the tide, when the bore, or tidal wave, which rises there about ten feet in perpendicular height, rushed into the estuary and overturned the vessel, so that it instantly disappeared. After the tide had ebbed, the schooner was so totally buried in the sand, that the taffrel or upper rail over the stern was alone visible.† We are informed by Leigh that, on draining Martin Meer, a lake eighteen miles in circumference, in Lancashire, a bed of marl was laid dry, wherein no fewer than eight canoes were found imbedded. In figure and dimensions they were not unlike those now used in America. In a morass about nine miles distant from this Meer a whetstone and an axe of mixed metal were dug up.‡ In Ayrshire, also, three canoes were found in Loch Doon some few years ago; and during the year 1831 four others, each hewn out of separate oak trees. They were twenty-three feet in length, two and a half in depth, and nearly four feet in breadth at the stern. In the mud which filled one of them was found a war-club of oak and a stone battle-axe. A canoe of oak was also found in 1820, in peat overlying the shell-marl of the Loch of Kinnordy in Forfarshire.§

Manner in which ships may be preserved in a deep

* Lieut. Carless, Geograph. Journ. vol. viii. p. 338.

† Silliman's Geol. Lectures, p. 78., who cites Penn.

‡ Leigh's Lancashire, p. 17., A. D. 1700.

§ Geol. Trans., second series, vol. ii. p. 87.

sea.—It is extremely possible that the submerged woodwork of ships which have sunk where the sea is two or three miles deep has undergone greater chemical changes in an equal space of time, than in the cases above mentioned; for the experiments of Scoresby show that wood may at certain depths be impregnated in a single hour with salt-water, so that its specific gravity is entirely altered. It may often happen that hot springs charged with carbonate of lime, silex, and other mineral ingredients, may issue at great depths, in which case every pore of the vegetable tissue may be injected with the lapidifying liquid, whether calcareous or siliceous, before the smallest decay commences. The conversion, also, of wood into lignite is probably more rapid under enormous pressure. But the change of the timber into lignite or coal would not prevent the original form of a ship from being distinguished: for as we find, in strata of the carboniferous era, the bark of the hollow reed-like trees converted into coal, and the central cavity filled with sandstone, so might we trace the outline of a ship in coal; while in the indurated mud, sandstone, or limestone, filling the interior, we might discover instruments of human art, ballast consisting of rocks foreign to the rest of the stratum, and other contents of the ship.

Submerged metallic substances.—Many of the metallic substances which fall into the waters probably lose, in the course of ages, the forms artificially imparted to them; but under certain circumstances these may be preserved for indefinite periods. The cannon inclosed in a calcareous rock, drawn up from the delta of the Rhone, which is now in the museum at Montpellier, might probably have endured as long

as the calcareous matrix; but even if the metallic matter had been removed, and had entered into new combinations, still a mould of its original shape would have been left, corresponding to those impressions of shells which we see in rocks, from which all the carbonate of lime has been subtracted. About the year 1776, says Mr. King, some fishermen, sweeping for anchors in the Gull stream (a part of the sea near the Downs), drew up a very curious old swivel gun, nearly eight feet in length. The barrel, which was about five feet long, was of brass; but the handle by which it was traversed was about three feet in length, and the swivel and pivot on which it turned were of iron. Around these latter were formed incrustations of sand converted into a kind of stone, of an exceedingly strong texture and firmness; whereas round the barrel of the gun, except where it was near adjoining to the iron, there was no such incrustation, the greater part of it being clean, and in good condition, just as if it had still continued in use. In the incrusting stone, adhering to it on the outside, were a number of shells and corallines, "just as they are often found in a fossil state." These were all so strongly attached, that it required as much force to separate them from the matrix "as to break a fragment off any hard rock."*

In the year 1745, continues the same writer, the Fox man-of-war was stranded on the coast of East Lothian, and went to pieces. About thirty-three years afterwards a violent storm laid bare a part of the wreck, and threw up near the place several masses, "consisting of iron, ropes, and balls," covered over with ochreous sand, concreted and hardened into a

* Phil. Trans., 1779.

kind of stone. The substance of the rope was very little altered. The consolidated sand retained perfect impressions of parts of an iron ring, "just as impressions of extraneous fossil bodies are found in various kinds of strata." *

After a storm in the year 1824, which occasioned a considerable shifting of the sands near St. Andrew's, in Scotland, a gun-barrel of ancient construction was found, which is conjectured to have belonged to one of the wrecked vessels of the Spanish Armada. It is now in the museum of the Antiquarian Society of Scotland, and is incrusted over by a thin coating of sand, the grains of which are cemented by brown ferruginous matter. Attached to this coating are fragments of various shells, as of the common cardium, mya, &c.

Many other examples are recorded of iron instruments taken up from the bed of the sea near the British coasts, incased by a thick coating of conglomerate, consisting of pebbles and sand, cemented by oxide of iron.

Dr. Davy describes a bronze helmet, of the antique Grecian form, taken up in 1825, from a shallow part of the sea, between the citadel of Corfu and the village of Castrades. Both the interior and exterior of the helmet were partially incrusted with shells, and a deposit of carbonate of lime. The surface generally, both under the incrustation, and where freed from it, was of a variegated colour, mottled with spots of green, dirty white, and red. On minute inspection with a lens, the green and red patches proved to consist of crystals of the red oxide and carbonate of copper, and the dirty white chiefly of oxide of tin.

* Phil. Trans. vol. lxix., 1779.

The mineralizing process, says Dr. Davy, which has produced these new combinations, has, in general, penetrated very little into the substance of the helmet. The incrustation and rust removed, the metal is found bright beneath; in some places considerably corroded, in others very slightly. It proves, on analysis, to be copper, alloyed with 18·5 per cent. of tin. Its colour is that of our common brass, and it possesses a considerable degree of flexibility.

"It is a curious question," he adds, "how the crystals were formed in the helmet, and on the adhering calcareous deposit. There being no reason to suppose deposition from solution, are we not under the necessity of inferring, that the mineralizing process depends on a small motion and separation of the particles of the original compound? This motion may have been due to the operation of electro-chemical powers which may have separated the different metals of the alloy."*

Effects of the Subsidence of Land, in imbedding Cities and Forests in subaqueous Strata.

We have hitherto considered the transportation of plants and animals from the land by *aqueous* agents, and their inhumation in lacustrine or submarine deposits, and we may now inquire what tendency the subsidence of tracts of land may have to produce analogous effects. Several examples of the sinking down of buildings, and portions of towns near the shore, to various depths beneath the level of the sea during subterranean movements, were before enumerated in treating of the changes brought about by *inorganic* causes. The events alluded to were comprised within

* Phil. Trans. 1826, part ii. p. 55.

a brief portion of the historical period, and confined to a small number of the regions of active volcanos. Yet these authentic facts, relating merely to the last century and a half, gave indications of considerable changes in the physical geography of the globe, and we are not to suppose that these were the only spots throughout the surrounding land and sea, which suffered similar depressions.

If, during the short period since South America has been colonized by Europeans, we have proof of alterations of level at the three principal ports on the western shores, Callao, Valparaiso, and Conception,* we cannot for a moment suspect that these cities, so distant from each other, have been selected as the peculiar points where the desolating power of the earthquake has expended its chief fury. "It would be a knowing arrow that could choose out the brave men from the cowards," retorted the young Spartan, when asked if his comrades who had fallen on the field of battle were braver than he and his fellow-prisoners; we might, in the same manner, remark that a geologist must attribute no small discrimination and malignity to the subterranean force, if he should suppose it to spare habitually a line of coast many thousand miles in length, with the exception of those few spots where populous towns have been erected. On considering how small is the area occupied by the seaports of this disturbed region,—points where alone each slight change of the relative level of the sea and land can be recognized, and reflecting on the proofs in our possession, of the local revolutions that have happened on the site of each port, within the last century and a half

* See Vol. II. pp. 297. 302. 370. 374.

— our conceptions must be greatly exalted respecting the magnitude of the alterations which the country between the Andes and the sea may have undergone, even in the course of the last six thousand years.

Cutch earthquake. — The manner in which a large extent of surface may be submerged, so that the terrestrial plants and animals may be imbedded in subaqueous strata, cannot be better illustrated than by the earthquake of Cutch, in 1819, before alluded to.* It is stated, that, for some years after that earthquake, the withered tamarisks and other shrubs protruded their tops above the waves, in parts of the lagoon formed by subsidence, on the site of the village of Sindree and its environs; but, after the flood of 1826, they were seen no longer. Every geologist will at once perceive, that forests sunk by such subterranean movements may become imbedded in subaqueous deposits, both fluviatile and marine, and the trees may still remain erect, or sometimes the roots and part of the trunks may continue in their original position, while the current may have broken off, or levelled with the ground, their upper stems and branches.

Buildings how preserved under water. — Some of the buildings which have at different times subsided beneath the level of the sea have been immediately covered up to a certain extent with strata of volcanic matter showered down upon them. Such was the case at Tomboro in Sumbawa, in the present century, and at the site of the Temple of Serapis, in the environs of Puzzuoli, probably in the 12th century. The entrance of a river charged with sediment in the vicinity may still more frequently occasion the rapid envelopment

* Vol. II. p. 306.

of buildings in regularly stratified formations. But if no foreign matter be introduced, the buildings, when once removed to a depth where the action of the waves is insensible, and where no great current happens to flow, may last for indefinite periods, and be as durable as the floor of the ocean itself, which may often be composed of the very same materials. There is no reason to doubt the tradition mentioned by the classic writers, that the submerged Grecian towns of Bura and Helice were seen under water; and it has been already mentioned that different eye-witnesses have observed the houses of Port Royal, at the bottom of the sea, at intervals of 88, 101, and 143 years after the convulsion of 1692.*

Berkeley's arguments for the recent date of the creation of man.—I cannot conclude this chapter without recalling to the reader's mind a memorable passage written by Bishop Berkeley a century ago, in which he inferred, on grounds which may be termed strictly geological, the recent date of the creation of man. "To any one," says he, "who considers that on digging into the earth, such quantities of shells, and in some places bones and horns of animals, are found sound and entire, after having lain there in all probability some thousands of years; it should seem probable that guns, medals, and implements in metal or stone might have lasted entire, buried under ground forty or fifty thousand years, if the world had been so old. How comes it then to pass that no remains are found, no antiquities of those numerous ages preceding the Scripture accounts of time; that no fragments of buildings, no public monuments, no intaglias, cameos, statues, basso-

* Vol. II. p. 380.

relievos, medals, inscriptions, utensils, or artificial works of any kind, are ever discovered, which may bear testimony to the existence of those mighty empires, those successions of monarchs, heroes, and demi-gods, for so many thousand years? Let us look forward and suppose ten or twenty thousand years to come, during which time we will suppose that plagues, famine, wars, and *earthquakes* shall have made great havoc in the world, is it not highly probable that at the end of such a period, pillars, vases, and statues now in being of granite, or porphyry, or jasper, (stones of such hardness as we know them to have lasted two thousand years above ground, without any considerable alteration,) would bear record of these and past ages? Or that some of our current coins might then be dug up, or old walls and the foundations of buildings show themselves, as well as the shells and stones of *the primeval world*, which are preserved down to our times." *

That many signs of the agency of man would have lasted at least as long as "the shells of the primeval world," had our race been so ancient, we may feel as fully persuaded as Berkeley; and we may anticipate with confidence that many edifices and implements of human workmanship and the skeletons of men, and casts of the human form, will continue to exist when a great part of the present mountains, continents, and seas, have disappeared. Assuming the future duration of the planet to be indefinitely protracted, we can foresee no limit to the perpetuation of some of the memorials of man, which are continually entombed in

* Alciphron, or the Minute Philosopher, vol. ii. pp. 84, 85. 1732.

the bowels of the earth or in the bed of the ocean, unless we carry forward our views to a period sufficient to allow the various causes of change, both igneous and aqueous, to remodel more than once the entire crust of the earth. *One* complete revolution will be inadequate to efface every monument of our existence; for many works of art might enter again and again into the formations of successive eras, and escape obliteration even though the very rocks in which they had been for ages imbedded were destroyed, just as pebbles included in the conglomerates of one epoch often contain the organized remains of beings which flourished during a prior era.

Yet it is no less true, as a late distinguished philosopher has declared, "that none of the works of a mortal being can be eternal." * They are in the first place wrested from the hands of man, and lost as far as regards their subserviency to his use, by the instrumentality of those very causes which place them in situations where they are enabled to endure for indefinite periods. And even when they have been included in rocky strata, when they have been made to enter as it were into the solid framework of the globe itself, they must nevertheless eventually perish; for every year some portion of the earth's crust is shattered by earthquakes or melted by volcanic fire, or ground to dust by the moving waters on the surface. "The river of Lethe," as Bacon eloquently remarks, "runneth as well above ground as below." †

* Davy, Consolations in Travel, p. 276.

† Essay on the Vicissitude of Things.

CHAPTER XVII.

IMBEDDING OF AQUATIC SPECIES IN SUBAQUEOUS STRATA.

Inhumation of fresh-water plants and animals — Shell marl — Fossilized seed-vessels and stems of chara — Recent deposits in American lakes — Fresh-water species drifted into seas and estuaries — Lewes levels — Alternations of marine and fresh-water strata, how caused — Imbedding of marine plants and animals — Cetacea stranded on our shores — Liability of littoral and estuary testacea to be swept into the deep sea — Effects of a storm in the Frith of Forth — Burrowing shells secured from the ordinary action of waves and currents — Living testacea found at considerable depths — Extent of some recent shelly deposits.

Having treated of the imbedding of terrestrial plants and animals, and of human remains, in deposits now forming beneath the waters, I come next to consider in what manner *aquatic* species may be entombed in strata formed in their own element.

Fresh-water plants and animals. — The remains of species belonging to those genera of the animal and vegetable kingdoms which are more or less exclusively confined to fresh water are for the most part preserved in the beds of lakes or estuaries, but they are oftentimes swept down by rivers into the sea, and there intermingled with the exuviæ of marine races. The phenomena attending their inhumation in lacustrine deposits are sometimes revealed to our observation by

the drainage of small lakes, such as are those in Scotland, which have been laid dry for the sake of obtaining shell marl for agricultural uses.

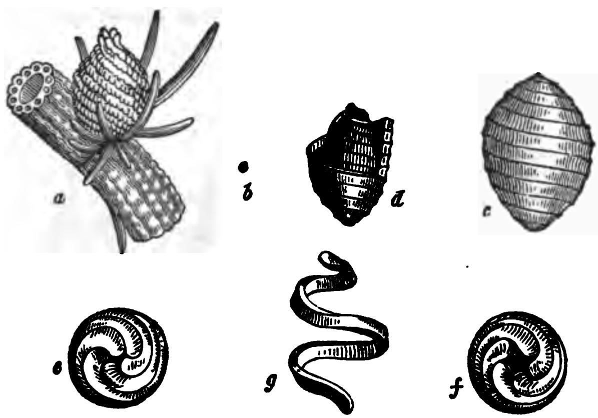
In these recent formations, as seen in Forfarshire, two or three beds of calcareous marl are sometimes observed separated from each other by layers of drift peat, sand, or fissile clay. The marl often consists almost entirely of an aggregate of shells of the genera limnea, planorbis, valvata, and cyclas, of species now existing in Scotland. A considerable proportion of the testacea appear to have died very young, and few of the shells are of a size which indicates their having attained a state of maturity. The shells are sometimes entirely decomposed, forming a pulverulent marl; sometimes in a state of good preservation. They are frequently intermixed with stems of charæ and other aquatic vegetables, the whole being matted together and compressed, forming laminæ often as thin as paper.

Fossilized seed-vessels and stems of chara.— As the chara is an aquatic plant, which occurs frequently fossil in formations of different eras, and is often of much importance to the geologist in characterizing entire groups of strata, I shall describe the manner in which I have found the recent species in a petrified state. They occur in a marl-lake in Forfarshire, inclosed in nodules, and sometimes in a continuous stratum of a kind of travertin.

The seed-vessel of these plants is remarkably tough and hard, and consists of a membranous nut covered by an integument (*d*, fig. 78.) both of which are spirally striated or ribbed. The integument is composed of five spiral valves, of a quadrangular form (*g*). In *Chara hispida*, which abounds in the lakes of Forfar-

shire, and which has become fossil in the Bakie Loch, each of the spiral valves of the seed-vessel turns rather more than twice round the circumference, the whole together making between ten and eleven rings. The number of these rings differs greatly in different species, but in the same appears to be very constant.

Fig. 78.



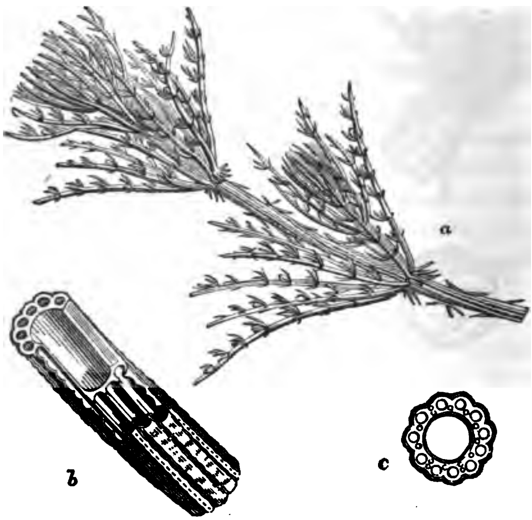
Seed-vessel of Chara hispida.

a, Part of the stem with the seed-vessel attached. Magnified.
b, Natural size of the seed-vessel.
c, Integument of the Gyrogonite, or petrified seed-vessel of *Chara hispida*, found in the Scotch marl-lakes. Magnified.
d, Section showing the nut within the integument.
e, Lower end of the integument to which the stem was attached.
f, Upper end of the integument to which the stigmata were attached.
g, One of the spiral valves of *c*.

The stems of charæ occur fossil in the Scotch marl in great abundance. In some species, as in *Chara hispida*, the plant when living contains so much carbonate of lime in its vegetable organization, independently of calcareous incrustation, that it effervesces strongly with acids when dry. The stems of *Chara*

hispida are longitudinally striated, with a tendency to be spiral. These striæ, as appears to be the case with all charæ, turn always like the worm of a screw from right to left, while those of the seed-vessel wind round in a contrary direction. A cross section of the stem exhibits a curious structure, for it is composed of a large tube surrounded by smaller tubes (fig. 79., *b*, *c*), as is seen in some extinct as well as recent species.

Fig. 79.



Stem and branches of Chara hispida.

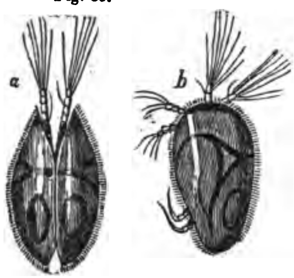
a, Stem and branches of the natural size.
b, Section of the stem magnified.
c, Showing the central tube surrounded by two rings of smaller tubes.

In the stems of several species, however, there is only a single tube.*

* On Fresh-water Marl, &c. By C. Lyell. Geol. Trans., vol. ii., second series, p. 73.

The valves of a small animal called cypris (*C. ornata?* Lam.) occur completely fossilized, like the stems of charæ, in the Scotch travertin above mentioned. The same cypris inhabits the lakes and ponds of England, where, together with many other species, it is not uncommon. Although extremely minute, they are visible to the naked eye, and may be observed in great numbers, swimming swiftly through the waters of our stagnant pools and ditches. The antennæ, at the end of

Fig. 80.



Cypris unifasciata, a living species, greatly magnified.
a, Upper part. *b*, Side view of the same.

Fig. 81.

Cypris vidua, a living species, greatly magnified.*

which are fine pencils of hair, are the principal organs for swimming, and are moved with great rapidity. The animal resides within two small valves, not unlike those of a bivalve shell, and moults its integuments annually, which the conchiferous mollusks do not. The cast-off shells resembling thin scales, and occurring in countless myriads in many ancient fresh-water marls, impart to them a divisional structure, like that so frequently derived from plates of mica.

Recent deposits in North American lakes.—The recent strata of lacustrine origin above alluded to are

* See Desmarest's Crustacea, pl. 55.

of very small extent, but analogous deposits on the grandest scale are forming in the great lakes of North America. By the subsidence of the waters of Lakes Superior and Huron, occasioned probably by the partial destruction of their barriers at some unknown period, beds of sand 150 feet thick are exposed, below which are seen beds of clay, inclosing shells of the very species which now inhabit the lake.*

But no careful examination appears as yet to have been made of recent fresh-water formations within the tropics, where the waters teem with life, and where in the bed of a newly-drained lake the remains of the alligator, crocodile, tortoise, and perhaps some large fish, might be discovered.

Imbedding of fresh-water Species in Estuary and Marine Deposits.

In Lewes levels.— We have sometimes an opportunity of examining the deposits which within the historical period have silted up some of our estuaries; and excavations made for wells and other purposes, where the sea has been finally excluded, enable us to observe the state of the organic remains in these tracts. The valley of the Ouze between Newhaven and Lewes is one of several estuaries from which the sea has retired within the last seven or eight centuries; and here, as appears from the researches of Mr. Mantell, strata thirty feet and upwards in thickness have accumulated. At the top, beneath the vegetable soil, is a bed of peat about five feet thick, inclosing many trunks of trees. Next below is a

* Dr. Bigsby, Journal of Science, &c. No. xxxvii. pp. 262, 263.

stratum of blue clay containing fresh-water shells of about nine species, such as now inhabit the district. Intermixed with these was observed the skeleton of a deer. Lower down, the layers of blue clay contain, with the above-mentioned fresh-water shells, several marine species well known on our coast. In the lowest beds, often at the depth of thirty-six feet, these marine testacea occur without the slightest intermixture of fluviatile species, and amongst them the skull of the narwal, or sea unicorn (*Monodon monoceros*), has been detected. Underneath all these deposits is a bed of pipe-clay, derived from the subjacent chalk.*

If we had no historical information respecting the former existence of an inlet of the sea in this valley and of its gradual obliteration, the inspection of the section above described would show, as clearly as a written chronicle, the following sequence of events. First, there was a salt-water estuary peopled for many years by species of marine testacea identical with those now living, and into which some of the larger cetacea occasionally entered. Secondly, the inlet grew shallower, and the water became brackish, or alternately salt and fresh, so that the remains of fresh-water and marine shells were mingled in the blue argillaceous sediment of its bottom. Thirdly, the shoaling continued until the river-water prevailed, so that it was no longer habitable by marine testacea, but fitted only for the abode of fluviatile species and aquatic insects. Fourthly, a peaty swamp or morass was formed, where some trees grew, or perhaps were

* Mantell, Geol. of Sussex, p. 285.; also Catalogue of Org. Rem., Geol. Trans., vol. iii part i. p. 201., second series.

drifted during floods, and where terrestrial quadrupeds were mired. Finally, the soil being flooded by the river only at distant intervals, became a verdant meadow.

In delta of Ganges.—It was before stated, that on the sea-coast, in the delta of the Ganges, there are eight great openings, each of which has evidently, at some ancient periods, served in its turn as the principal channel of discharge.* Now, as the base of the delta is 200 miles in length, it must happen that, as often as the great volume of river-water is thrown into the sea by a new mouth, the sea will at one point be converted from salt to fresh, and at another from fresh to salt; for, with the exception of those parts where the principal discharge takes place, the salt-water not only washes the base of the delta, but enters far into every creek and lagoon. It is evident, then, that repeated alternations of beds containing fresh-water shells, with others filled with corals and marine exuviæ, may here be formed; and each series may be of great thickness, as the sea on which the Gangetic delta gains is of considerable depth, and intervals of centuries elapse between each alteration in the course of the principal stream.

In delta of Indus.—Analogous phenomena must sometimes be occasioned by such alternate elevation and depression of the land as was shown to be taking place in the delta of the Indus.† But the subterranean movements affect but a small number of the deltas formed at one period on the globe; whereas, the silting up of some of the arms of great rivers and the opening of others, and the consequent variation of

* Vol. II. p. 3. † Vol. II. p. 307.

the points where the chief volume of their waters is discharged into the sea, are phenomena common to almost every delta.

The variety of species of testacea contained in the recent calcareous marl of Scotland, before mentioned, is very small, but the abundance of individuals extremely great, a circumstance very characteristic of fresh-water formations in general, as compared to marine; for in the latter, as is seen on sea-beaches, coral reefs, or in the bottom of seas examined by dredging, wherever the individual shells are exceedingly numerous, there rarely fails to be a vast variety of species.

Imbedding of the Remains of Marine Plants and Animals.

Marine Plants.—The large banks of drift sea-weed which occur on each side of the equator in the Atlantic, Pacific, and Indian oceans, were before alluded to.* These, when they subside, may often produce considerable beds of vegetable matter. In Holland, submarine peat is derived from fuci, and on parts of our own coast from *Zostera marina.* In places where algæ do not generate peat, they may nevertheless leave traces of their form imprinted on argillaceous and calcareous mud, as they are usually very tough in their texture.

Cetacea.—It is not uncommon for the larger cetacea, which can float only in a considerable depth of water, to be carried during storms or high tides into estuaries, or upon low shores, where, upon the retiring of high water, they are stranded. Thus a narwal (*Monodon*

* Page 99.

monoceros) was found on the beach near Boston in Lincolnshire, in the year 1800, the whole of its body buried in the mud. A fisherman going to his boat saw the horn and tried to pull it out, when the animal began to stir itself.* An individual of the common whale (*Balæna mysticetus*), which measured seventy feet, came ashore near Peterhead, in 1682. Many individuals of the genus Balænoptera have met the same fate. It will be sufficient to refer to those cast on shore near Burnt Island, and at Alloa, recorded by Sibbald and Neill. The other individual mentioned by Sibbald, as having come ashore at Boyne, in Banffshire, was probably a razor-back. Of the genus Catodon (*Cachalot*), Ray mentions a large one stranded on the west coast of Holland in 1598, and the fact is also commemorated in a Dutch engraving of the time of much merit. Sibbald, too, records that a herd of Cachalots, upwards of 100 in number, were found stranded at Kairston, in Orkney. The dead bodies of the larger cetacea are sometimes found floating on the surface of the waters, as was the case with the immense whale exhibited in London in 1831. And the carcass of a sea-cow or Lamantine (*Halicora*) was, in 1785, cast ashore near Leith.

To some accident of this kind, we may refer the position of the skeleton of a whale, seventy-three feet long, which was found at Airthrey, on the Forth, near Stirling, imbedded in clay twenty feet higher than the surface of the highest tide of the river Forth at the present day. From the situation of the Roman station and causeways at a small distance from the spot, it is

* Fleming's Brit. Animals, p. 37.; in which work may be seen many other cases enumerated.

concluded that the whale must have been stranded there at a period prior to the Christian era.*

Other fossil remains of this class have also been found in estuaries, known to have been silted up in recent times, one example of which has been already mentioned near Lewes, in Sussex.

Marine reptiles.— Some singular fossils have lately been discovered in the island of Ascension, in a stone said to be continually forming on the beach, where the waves throw up small rounded fragments of shells and corals, which, in the course of time, become firmly agglutinated together, and constitute a stone used largely for building and making lime. In a quarry on the N.W. side of the island, about 100 yards from the sea, some fossil eggs of turtles have been discovered in the hard rock thus formed. The eggs must have been nearly hatched at the time when they perished; for the bones of the young turtle are seen in the interior, with their shape fully developed, the interstices between the bones being entirely filled with grains of sand, which are cemented together, so that when the egg-shells are removed perfect casts of their form remain in stone. In the single specimen here figured (Fig. 82.), which is only five inches in its longest diameter, no less than seven eggs are preserved.‡

Fig. 82.

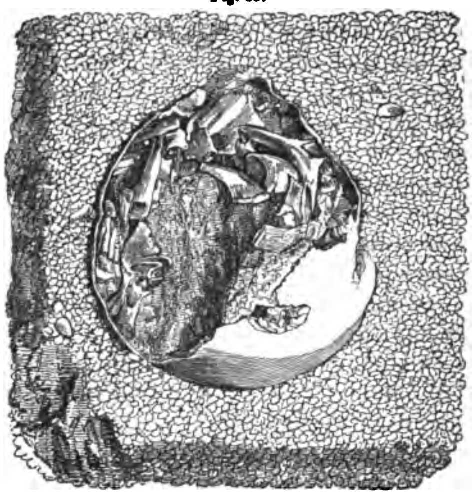
Fossil eggs of Turtles from the Island of Ascension.†

* Quart. Journ. of Lit. Sci., &c. No. xv. p. 172. Oct. 1819.

† This specimen has been presented by Mr. Lonsdale to the Geological Society of London.

‡ The most conspicuous of the bones represented within the

Fig. 83.



One of the eggs in Fig. 82. of the natural size, showing the bones of the fœtus which had been nearly hatched.

To explain the state in which they occur fossil, it seems necessary to suppose that after the eggs were almost hatched in the warm sand, a great wave threw upon them so much more sand as to prevent the rays of the sun from penetrating, so that the yolk was

shell in Fig. 83., appear to be the clavicle and coracoid bone. They are hollow ; and for this reason resemble, at first sight, the bones of birds rather than of reptiles; for the latter have no medullary cavity. Mr. Owen, of the College of Surgeons, in order to elucidate this point, dissected for me a very young turtle, and found that the exterior portion only of the bones was ossified, the interior being still filled with cartilage. This cartilage soon dried up, and shrank to a mere thread upon the evaporation of the spirits of wine in which the specimen had been preserved, so that in a short time the bones became as empty as those of birds.

chilled and deprived of vitality. The shells were perhaps slightly broken at the same time, so that small grains of sand might gradually be introduced into the interior by water as it percolated through the beach.

Marine testacea. — The aquatic animals and plants which inhabit an estuary are liable, like the trees and land animals which people the alluvial plains of a great river, to be swept from time to time far into the deep; for as a river is perpetually shifting its course, and undermining a portion of its banks with the forests which cover them, so the marine current alters its direction from time to time, and bears away the banks of sand and mud, against which it turns its force. These banks may consist in great measure of shells peculiar to shallow, and sometimes brackish water, which may have been accumulating for centuries, until at length they are carried away and spread out along the bottom of the sea, at a depth at which they could not have lived and multiplied. Thus littoral and estuary shells are more frequently liable even than freshwater species, to be intermixed with the exuviæ of pelagic tribes.

After the storm of February 4. 1831, when several vessels were wrecked in the estuary of the Forth, the current was directed against a bed of oysters with such force, that great heaps of them were thrown *alive* upon the beach, and remained above high water mark. I collected many of these oysters, as also the common eatable whelks (*buccina*), thrown up with them, and observed that, although still living, their shells were worn by the long attrition of sand which had passed over them as they lay in their native bed, and which had evidently not resulted from the mere action of the tempest by which they were cast ashore.

From these facts we learn that the union of the two parts of a bivalve shell does not prove that it has not been transported to a distance; and when we find shells worn, and with all their prominent parts rubbed off, they may still have been imbedded where they grew.

Burrowing shells. — It sometimes appears extraordinary, when we observe the violence of the breakers on our coast, and see the strength of the current in removing cliffs, and sweeping out new channels, that many tender and fragile shells should inhabit the sea in the immediate vicinity of this turmoil. But a great number of the bivalve testacea, and many also of the turbinated univalves, burrow in sand or mud. The solen and the cardium, for example, which are usually found in shallow water near the shore, pierce through a soft bottom without injury to their shells; and the pholas can drill a cavity through mud of considerable hardness. The species of these and many other tribes can sink, when alarmed, with considerable rapidity, often to the depth of several feet, and can also penetrate upwards again to the surface, if a mass of matter be heaped upon them. The hurricane, therefore, may expend its fury in vain, and may sweep away even the upper part of banks of sand or mud, or may roll pebbles over them, and yet these testacea may remain below secure and uninjured.

Shells become fossil at considerable depths. — I have already stated that, at the depth of 950 fathoms, between Gibraltar and Ceuta, Captain Smith found a gravelly bottom, with fragments of broken shells, carried thither probably from the comparatively shallow parts of the neighbouring straits, through which a powerful current flows. Beds of shelly sand might

here, in the course of ages, be accumulated several thousand feet thick. But, without the aid of the drifting power of a current, shells may accumulate in the spot where they live and die, at great depths from the surface, if sediment be thrown down upon them; for even in our own colder latitudes, the depths at which living marine animals abound is very considerable. Captain Vidal ascertained, by soundings made off Tory Island, on the north-west coast of Ireland, that crustacea, star-fish, and testacea, occurred at various depths between fifty and one hundred fathoms; and he drew up dentalia from the mud of Galway bay, in 230 and 240 *fathoms* water.

The same hydrographer discovered on the Rockall bank large quantities of shells at depths varying from 45 to 190 fathoms. These shells were for the most part pulverized, and evidently recent, as they retained their bright colours. In the same region a bed of fish-bones was observed extending for two miles along the bottom of the sea in eighty and ninety fathoms water. At the eastern extremity also of Rockall bank fish-bones were met with, mingled with pieces of fresh shell, at the depth of 235 fathoms.

Analogous formations are in progress in the submarine tracts extending from the Shetland Isles to the north of Ireland, wherever soundings can be procured. A continuous deposit of sand and mud, replete with broken and entire shells, echini, &c., has been traced for upwards of twenty miles to the eastward of the Faroe Islands, usually at the depth of from forty to one hundred fathoms. In one part of this tract (lat. 61° 50′, long. 6° 30′) fish-bones occur in extraordinary profusion, so that the lead cannot be drawn up without some vertebræ being attached. This "bone bed,"

as it was called by our surveyors, is three miles and a half in length, and forty-five fathoms under water, and contains a few shells intermingled with the bones.

In the British seas, the shells and other organic remains lie in soft mud or loose sand and gravel; whereas, in the bed of the Adriatic, Donati found them frequently inclosed in stone of recent origin. This is precisely the difference in character which we might have expected to exist between the British marine formations now in progress, and those of the Adriatic; for calcareous and other mineral springs abound in the Mediterranean and lands adjoining, while they are almost entirely wanting in our own country.

During his survey of the west coast of Africa, Captain Belcher found, by frequent soundings between the twenty-third and twentieth degrees of north latitude, that the bottom of the sea, at the depth of from twenty to about fifty fathoms, consists of sand with a great intermixture of shells, often entire, but sometimes finely comminuted. Between the eleventh and ninth degrees of north latitude, on the same coast, at soundings varying from twenty to about eighty fathoms, he brought up abundance of corals and shells mixed with sand. These also were in some parts entire, and in others worn and broken.

In all these cases, it is only necessary that there should be some deposition of sedimentary matter, however minute, such as may be supplied by rivers draining a continent, or currents preying on a line of cliffs, in order that stratified formations, hundreds of feet in thickness, and replete with organic remains, should result in the course of ages.

But although some deposits may thus extend continuously for a thousand miles or more near certain coasts, the greater part of the bed of the ocean, remote from continents and islands, may very probably receive, at the same time, no new accessions of drift matter, all sediment being intercepted by intervening hollows. Erroneous theories in geology may be formed not only from overlooking the great extent of simultaneous deposits now in progress, but also from the assumption that such formations may be universal or coextensive with the bed of the ocean.

CHAPTER XVIII.

FORMATION OF CORAL REEFS.

Growth of coral chiefly confined to tropical regions — Principal genera of coral-building zoophytes — Their rate of growth — Seldom flourish at greater depths than twenty fathoms — Atolls or annular reefs with lagoons — Maldiva Isles — Origin of the circular form — Coral reefs not based on submerged volcanic craters — Mr. Darwin's theory of subsidence in explanation of circular reefs or atolls — Equally applicable to encircling and barrier reefs — Why the windward side of atolls highest — Subsidence explains why all atolls are nearly on one level — Alternate areas of elevation and subsidence — Probable thickness and shape of coral formations under water according as the motion has been upward or downward, continuous in one direction or oscillatory, slow or rapid, uniform or intermittent — Origin of openings into the lagoons — Size of atolls and barrier reefs — Stratification — Lime whence derived — Supposed increase of calcareous matter in modern epochs controverted — Concluding remarks.

The powers of the organic creation in modifying the form and structure of the earth's crust, are most conspicuously displayed in the labours of the coral animals. We may compare the operation of these zoophytes in the ocean, to the effects produced on a smaller scale upon the land by the plants which generate peat. In the case of the Sphagnum, the upper part vegetates

while the lower portion is entering into a mineral mass, in which the traces of organization remain when life has entirely ceased. In corals, in like manner, the more durable materials of the generation that has passed away serve as the foundation on which the living animals continue to rear a similar structure.

The stony part of the lamelliform zoophyte may be likened to an internal skeleton; for it is always more or less surrounded by a soft animal substance capable of expanding itself; yet, when alarmed, it has the power of contracting and drawing itself almost entirely into the cells and hollows of the hard coral. Although oftentimes beautifully coloured in their own element, the soft parts become when taken from the sea nothing more in appearance than a brown slime spread over the stony nucleus.*

The growth of those corals which form reefs of solid stone is entirely confined to the warmer regions of the globe, rarely extending beyond the tropics above two or three degrees, except under peculiar circumstances, as in the Bermuda islands, in lat. 32° N., where the Atlantic is warmed by the gulf stream. The Pacific Ocean, throughout a space comprehended between the thirtieth parallels of latitude on each side of the equator, is extremely productive of coral; as also are the Arabian and Persian Gulfs. Coral is also abundant in the sea between the coast of Malabar and the island of Madagascar. Flinders describes a reef of coral on the east coast of New Holland as having a length of nearly 1000 miles, and as being in one part

* Ehrenberg, Nat. und Bild. der Coralleninseln, &c., Berlin, 1834.

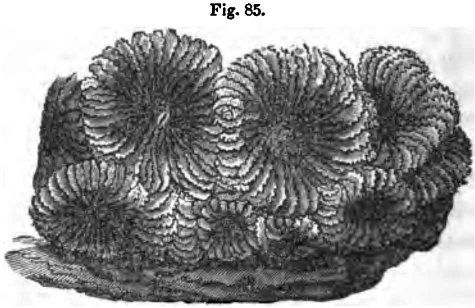
unbroken for a distance of 350 miles. Some groups of coral islands in the Pacific are from 1100 to 1200 miles in length, by 300 or 400 in breadth, as the Dangerous Archipelago, for example, and that called Radack by Kotzebue; but the islands within these spaces are always small points, and often very thinly sown.

Fig. 84.

Meandrina labyrinthica, Lam.

Of the numerous species of zoophytes which are engaged in the production of coral banks, some of the most common belong to the Lamarckian genera Astrea, Porites, Madrepora, Millepora, Caryophyllia, and Meandrina.

Fig. 85.



Astrea dipsacea, Lam.

Genera of Zoophytes most common in coral reefs.

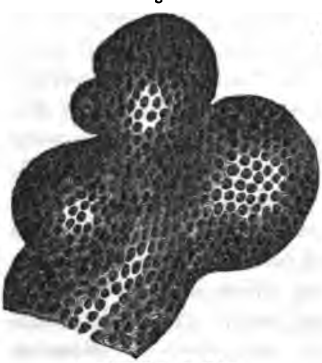
Fig. 86.

Extremity of branch of Madrepora muricata, Lin.

Fig. 87.

Caryophyllia fastigiata, Lam.

Fig. 88.



Porites clavaria, Lam.

Fig. 89.

Oculina hirtella, Lam.

Rate of the growth of coral.— Very different opinions have been entertained in regard to the rate at which coral reefs increase. In Captain Beechey's late expedition to the Pacific, no positive information could be obtained of any channel having been filled up within a given period; and it seems established, that several reefs had remained, for more than half a century, at about the same depth from the surface.

Ehrenberg also questions the fact of channels and harbours having been closed up in the Red Sea by the rapid increase of coral limestone. He supposes the notion to have arisen from the circumstance of havens having been occasionally filled up in some places with coral sand, in others with large quantities of ballast of coral rock thrown down from vessels.

The natives of the Bermuda Islands point out certain corals now growing in the sea, which, according to tradition, have been living in the same spots for centuries. It is supposed that some of them may vie in age with the most ancient trees of Europe. Ehrenberg also observed single corals of the genera Meandrina and Favia, having a globular form, from six to nine feet in diameter, "which must (he says) be of immense antiquity, probably several thousand years old, so that Pharaoh may have looked upon these same individuals in the Red Sea."* They certainly imply, as he remarks, that the reef on which they grow has increased at a very slow rate. After collecting more than 100 species, he found none of them covered with parasitic zoophytes, nor any instance of a living coral growing on another living coral. To this repulsive power which they exert whilst living, against all

* Ehrenberg, as before cited, p. 367.

others of their own class, we owe the beautiful symmetry of some large Meandrinæ, and other species which adorn our museums. Yet balani and serpulæ can attach themselves to living corals, and holes are excavated in them by saxicavous mollusca. On the other hand, an oyster which cannot have been more than two years old when taken, is preserved in the museum of the Bristol Institution, enveloped by a dense coral, a species of Agaricia, weighing 2lb. 9oz.* At the island called Taaopoto, in the South Pacific, the anchor of a ship, wrecked about 50 years before, was observed in seven fathom water, still preserving its original form, but entirely incrusted by coral.†

This fact would seem to imply a slow rate of augmentation; but to form a correct estimate of the average rate must be very difficult, since it must vary not only according to the species of coral, but according to the circumstances under which each species may be placed; such, for example, as the depth from the surface, the quantity of light, the temperature of the water, its freedom from sand or mud, or the absence or presence of breakers, which is favourable to the growth of some kinds and is fatal to that of others.

It should also be observed that the apparent stationary condition of some coral reefs, which according to Beechey have remained for centuries at the same depth under water, may be due to subsidence, the upward growth of the coral having been just sufficient to keep pace with the sinking of the solid foundation on which the zoophytes have built. We shall afterwards see how far this hypothesis is borne out by other evidence in the regions of annular reefs or atolls.

* Stutchbury, West of England Journal, No. i. p. 51.

† Ibid, p. 49.

It must not be supposed that the calcareous masses termed coral reefs are exclusively the work of zoophytes; a great variety of shells, and, among them, some of the largest and heaviest of known species, contribute to augment the mass. In the South Pacific, great beds of oysters, muscles, *pinnæ marinæ*, *chamæ* (or *tridacnæ*), and other shells, cover in profusion almost every reef; and, on the beach of coral islands, are seen the shells of echini and broken fragments of crustaceous animals. Large shoals of fish are also discernible through the clear blue water, and their teeth and hard palates cannot fail to be often preserved, although their soft cartilaginous bones may decay.

It was the opinion of the German naturalist Forster, in 1780, after his voyage round the world with Captain Cook, that coral animals had the power of building up steep and almost perpendicular walls from great depths in the sea, a notion afterwards adopted by Captain Flinders and others; but it is now very generally believed that these zoophytes cannot live in water of great depths.

Mr. Darwin has come to the conclusion, that those species which are most effective in the construction of reefs, rarely flourish at a greater depth than 20 fathoms, or 120 feet. Ehrenberg, after devoting more than a year to the examination of the corals of the Red Sea, conceives that they do not grow there at depths exceeding eight fathoms;* although there are various species of zoophytes, and among them some which are provided with calcareous as well as horny stems, which live in much deeper water, even in some cases to a depth of 180 fathoms. MM.

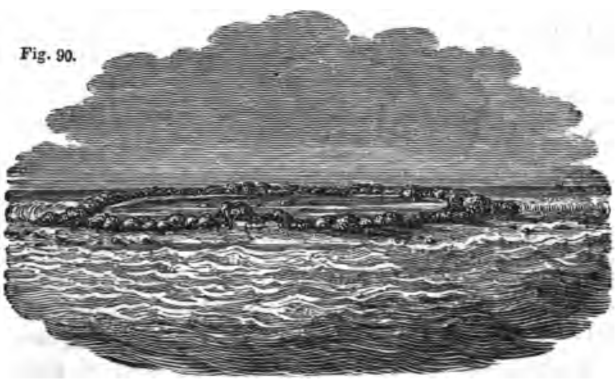
* Ehrenberg, Nat. und Bild. der Coralleninseln, &c., Berlin, 1834.

Quoy and Gaimard were certainly much mistaken in thinking that the species which contribute most actively to the formation of solid masses, do not grow in water beyond the depth of four or five fathoms. It has been suggested that the branched madrepores, which live at the greatest depth, may form the first foundation of a reef, and possibly raise a platform on which other species may afterwards build;* but there is at present no proof of reefs having originated in this manner.

There is every variety of form in coral reefs, but the most remarkable and numerous in the Pacific consist of circular or oval strips of dry land, enclosing a shallow lake or lagoon of still water, in which zoophytes and mollusca abound. These annular reefs just raise themselves above the level of the sea, and are surrounded by a deep and often unfathomable ocean.

In the annexed cut (Fig. 90.), one of these circular

Fig. 90.



View of Whitsunday Island. (Capt. Beechey.) †

* Journ. of Roy. Geograph. Soc. 1831, p. 218.

† Voyage to the Pacific, &c. in 1825–28.

islands is represented, just rising above the waves, covered with the cocoa-nut and other trees, and inclosing within a lagoon of tranquil water.

The accompanying section will enable the reader to comprehend the usual form of such islands. (Fig. 91.)

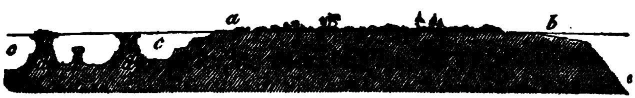
Fig. 91.

Section of a Coral Island.

a, *a*, Habitable part of the Island, consisting of a strip of coral, inclosing the lagoon.
b, *b*, The lagoon.

The subjoined cut (Fig. 92.) exhibits a small part of the section of a coral island on a larger scale.

Fig. 92.



Section of part of a Coral Island.

a b, Habitable part of the island.
b e, Slope of the side of the island, plunging at an angle of forty-five to the depth of fifteen hundred feet.
c c, Part of the lagoon.
d d, Knolls of coral in the lagoon, with overhanging masses of coral resembling the capitals of columns.

Of thirty-two of these coral islands visited by Beechey in his voyage to the Pacific, twenty-nine had lagoons in their centres. The largest was 30 miles in diameter, and the smallest less than a mile. All were increasing their dimensions by the active operations of the lithophytes, which appeared to be gradually extending and bringing the immersed parts of their structure to the surface. The scene presented by these annular reefs is equally striking for its singularity and beauty. A strip of land a few hundred

yards wide is covered by lofty cocoa-nut trees, above which is the blue vault of heaven. This band of verdure is bounded by a beach of glittering white sand, the outer margin of which is encircled with a ring of snow-white breakers, beyond which are the dark heaving waters of the ocean. The inner beach incloses the still clear water of the lagoon, resting in its greater part on white sand, and, when illuminated by a vertical sun, of a most vivid green.* Certain species of zoophytes abound most in the lagoon, others on the exterior margin, where there is a great surf. "The ocean," says Mr. Darwin, "throwing its breakers on these outer shores, appears an invincible enemy, yet we see it resisted and even conquered by means which at first seem most weak and inefficient. No periods of repose are granted, and the long swell caused by the steady action of the trade wind never ceases. The breakers exceed in violence those of our temperate regions, and it is impossible to behold them without feeling a conviction that rocks of granite or quartz would ultimately yield and be demolished by such irresistible forces. Yet these low insignificant coral islets stand and are victorious, for here another power, as antagonist to the former, takes part in the contest. The organic forces separate the atoms of carbonate of lime one by one from the foaming breakers, and unite them into a symmetrical structure; myriads of architects are at work night and day, month after month, and we see their soft and gelatinous bodies through the agency of the vital laws conquering the great mechanical power of the waves of an ocean, which neither the art of

* Darwin's Journal, &c. p. 540.

man, nor the inanimate works of nature could successfully resist."*

As the coral animals require to be continually immersed in salt water, they cannot raise themselves by their own efforts above the level of the lowest tides. The manner in which the reefs are converted into islands above the level of the sea is thus described by Chamisso, a naturalist who accompanied Kotzebue in his voyages:—"When the reef," says he, "is of such a height that it remains almost dry at low water the corals leave off building. Above this line a continuous mass of solid stone is seen composed of the shells of mollusks and echini, with their broken-off prickles and fragments of coral, united by calcareous sand, produced by the pulverization of shells. The heat of the sun often penetrates the mass of stone when it is dry, so that it splits in many places, and the force of the waves is thereby enabled to separate and lift blocks of coral, frequently six feet long and three or four in thickness, and throw them upon the reef, by which means the ridge becomes at length so high that it is covered only during some seasons of the year by the spring tides. After this the calcareous sand lies undisturbed, and offers to the seeds of trees and plants cast upon it by the waves a soil upon which they rapidly grow, to overshadow its dazzling white surface. Entire trunks of trees, which are carried by the rivers from other countries and islands, find here, at length, a resting-place after their long wanderings: with these come some small animals, such as insects and lizards, as the first inhabitants. Even before the trees form a wood, the sea-birds nestle here; strayed land-birds take

* Darwin's Journal, &c. pp. 547, 548.

refuge in the bushes; and, at a much later period, when the work has been long since completed, man appears and builds his hut on the fruitful soil." *

In the above description the solid stone is stated to consist of shell, and coral, united by sand; but masses of very compact limestone are also found even in the uppermost and newest parts of the reef, such as could only have been produced by chemical precipitation.

In these instances the carbonate of lime may have been derived from the decomposition of corals and testacea; for when the animal matter undergoes putrefaction, the calcareous residuum must be set free under circumstances very favourable to precipitation, especially when there are other calcareous substances, such as shells and corals on which it may be deposited. Thus organic bodies may be inclosed in a solid cement, and become portions of rocky masses. †

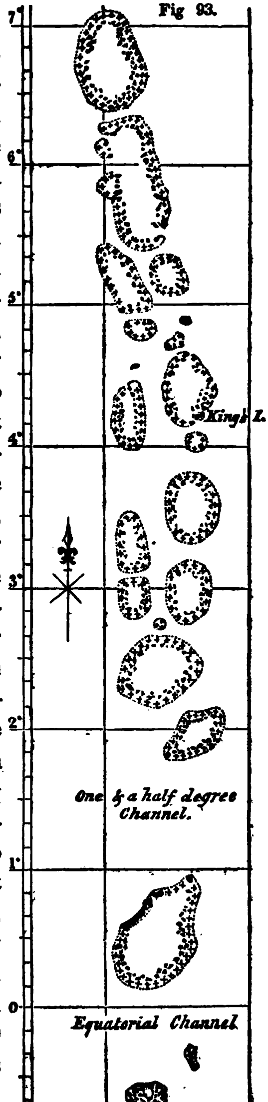
The width of the circular strip of dead coral forming the islands explored by Captain Beechey, exceeded in no instance half a mile from the usual wash of the sea to the edge of the lagoon, and, in general, was only about three or four hundred yards.‡ The depth of the lagoons is various; in some, entered by Captain Beechey, it was from twenty to thirty-eight fathoms.

The two other peculiarities which are most characteristic of the annular reef or atoll is first, that the strip of dead coral is invariably highest on the windward side, and secondly that there is very generally an opening at some point in the reef affording a narrow passage, often of considerable depth, from the sea into the lagoon.

* Kotzebue's Voyages, 1815–18, vol. iii. pp. 331—333.

† Stutchbury, West of Eng. Journ., No. i. p. 50.

‡ Captain Beechey, part i. p. 188.



Maldiva and Laccadive Isles. — The chain of reefs and islets called the Maldivas (see fig. 93.), situated in the Indian Ocean, to the south-west of Malabar, form a chain 480 geographical miles in length, running due north and south. It is composed throughout of a series of circular assemblages of islets, all formed of coral, the larger groups being from forty to ninety miles in their longest diameter. Captain Horsburgh, whose chart of these islands is subjoined, states, that outside of each circle or *atoll*, as it is termed, there are coral reefs sometimes extending to the distance of two or three miles, beyond which there are no soundings at immense depths. But in the centre of each atoll there is a lagoon from fifteen to forty fathoms deep. In the channels between the atolls, no soundings were obtained at the depth of 150 fathoms, but I understand that they have since been found, in some places, during Captain Moresby's survey, within 200 fathoms. Each atoll consists of a ring of islands instead

of one continuous and circular reef, there being sometimes more than 100 islands in one atoll, each island varying from half a mile to two miles in length. They are composed of sandstone formed of broken shells and corals, such as may be obtained in a loose state from the beach, and which is seen when exposed for a few days to the air to become hardened. The sandstone is sometimes observed to be an aggregate of broken shells, corals, pieces of wood, and shells of the cocoa-nut.*

The Laccadive islands run in the same line with the Maldivas, on the north, as do the isles of the Chagos Archipelago, on the south; so that these may be continuations of the same chain of submerged mountains, crested in a similar manner by coral limestones.

Origin of the circular form — not volcanic. — The circular and oval shape of so many reefs, each having a lagoon in the centre, and being surrounded on all sides by a deep ocean, naturally suggested the idea that they were nothing more than the crests of submarine volcanic craters overgrown by coral; and this theory I myself advocated in former editions. Although I am now about to show that it must be abandoned, it may still be instructive to point out the grounds on which it was formerly embraced. In the first place it had been remarked that there were many active volcanos in the coral region of the Pacific, and that in some places, as in Gambier's group, rocks composed of porous lava rise up in a lagoon bordered by a circular reef, just as the two cones of eruption called the Kamenis, have made their appearance in the times of

* Captain Moresby on the Maldivas, Journ. Roy. Geograph. Soc. vol. v. part ii. p. 400.

history within the circular gulf of Santorin.* It was also observed that as in S. Shetland, Barren Island, and others of volcanic origin, there is one narrow breach in the walls of the outer cone by which ships may enter a circular gulf, so in like manner is there often a single deep passage leading into the lagoon of a coral island, the lagoon itself seeming to represent the hollow or gulph just as the ring of dry coral recalls the rim of a volcanic crater.

Another argument which I adduced when formerly defending this doctrine was derived from Ehrenberg's statement, that some banks of coral in the Red Sea were square, while many others were ribbon-like strips, with flat tops, and without lagoons. Since, therefore, all the genera and many of the species of zoophytes in the Red Sea agreed with those which elsewhere construct lagoon islands, it followed that the stone-making zoophytes are not guided by their own instinct in the formation of annular reefs, but that this peculiar shape and the position of such reefs in the midst of a deep ocean must depend on the outline of the submarine bottom, which nothing else in nature resembles but the crater of a lofty submerged volcanic cone. The enormous size, it is true, of some atolls made it necessary for me to ascribe to the craters of many submarine volcanos a magnitude which was startling, and which had often been appealed to as a serious objection to the volcanic theory.

May be explained by subsidence. — Mr. Darwin, after examining a variety of coral formations in different parts of the globe, was induced to reject the opinion that their shape represented the form of the original

* See Vol. II. p. 282.

bottom. Instead of admitting that the ring of dead coral rested on a circular or oval ridge of rock, or that the lagoon corresponded to a pre-existing cavity, he advanced a new opinion, which must, at first sight, seem paradoxical in the extreme; namely, that the lagoon is precisely in the place which the top of a shoal, or, in other cases, the highest part of a mountainous island, once occupied. The following is a brief sketch of the facts and arguments in favour of this new view.

Besides those rings of dry coral which inclose lagoons, there are others having a similar form and structure which encircle lofty islands. Of the latter kind is Vanikoro, celebrated on account of the shipwreck of La Peyrouse, where the coral reef runs at the distance of two or three miles from the shore, the channel between it and the land having a general depth of between 200 and 300 feet. This channel, therefore, is analogous to a lagoon, but with an island standing in the middle like a picture in its frame. In like manner in Tahiti we see a mountainous land with every where round its margin a lake or zone of smooth salt water, separated from the ocean by an encircling reef of coral, on which a line of breakers are always foaming. So also New Caledonia, a long narrow island east of New Holland, in which the rocks are granitic, is surrounded by a reef which runs for a length of 400 miles. This reef encompasses not only the island itself, but a ridge of rocks which are prolonged in the same direction beneath the sea. No one, therefore, will contend for a moment that in this case the corals are based upon the rim of a volcanic crater, in the middle of which stands a mountain or island of granite.

The great barrier reef, already mentioned as run-

ning parallel to the north-east coast of Australia for nearly 1000 miles, is another most remarkable example of a long strip of coral running parallel to a coast. Its distance from the mainland varies from twenty to seventy miles, and the depth of the great arm of the sea thus inclosed is usually between ten and twenty fathoms, but towards one end from forty to sixty.

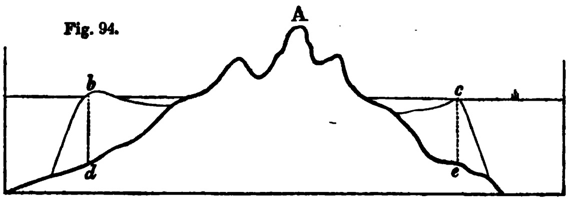
Two classes of reefs, therefore, have now been considered; first, the atoll, and, secondly, the encircling and barrier reef, all agreeing perfectly in structure, and the sole difference lying in the absence in the case of the atoll of all land, and its presence in the other cases whether as an encircled island or continent bordered by a barrier. But there is still a third class of reefs, called by Mr. Darwin "fringing reefs," which approach much nearer the land than those of the encircling and barrier class, and which indeed so nearly touch the coast as to leave nothing in the intervening space resembling a lagoon. "That these reefs are not attached quite close to the shore appears to be the result of two causes; first, that the water immediately adjoining the beach is rendered turbid by the surf, and therefore injurious to all zoophytes; and, secondly, that the larger and efficient kinds only flourish on the outer edge amidst the breakers of the open sea." *

It will at once be conceded that there is so much analogy between the form and position of the strip of coral in the atoll, and in the encircling and barrier reef, that no explanation can be satisfactory which does not include the whole. If we turn in the first place to the encircling and barrier reefs, and endeavour to explain

* Darwin's Journal, p. 557.

how the zoophytes could have found a bottom on which to begin to build, we are met at once with a great difficulty. It is a general fact, long since remarked by Dampier, that high land and deep seas go together. In other words, steep mountains coming down abruptly to the sea-shore are generally continued with the same slope beneath the water. But where the reef, as at *b* and *c* (fig. 94.), is distant several miles from a steep coast, a line drawn perpendicularly downwards from its outer edges *b c* to the fundamental rock *d e*, must descend to a depth exceeding by several thousand feet

Fig. 94.



Supposed section of an Island with an encircling reef of Coral.

A, The island.
b c, Highest points of the encircling reef between which and the coast is seen a space occupied by still water.

the limits at which the efficient stone-building corals can exist, for we have seen that they cease to grow in water which is more than 120 feet deep. That the original rock immediately beneath the points *b c* is actually as far from the surface as *d e*, is not merely inferred from Dampier's rule, but confirmed by the fact, that immediately outside the reef, soundings are either not met with at all, or only at enormous depths. In short, the ocean is as deep there as might have been anticipated in the neighbourhood of a bold coast; and it is obviously the presence of the coral alone which has given rise to the anomalous existence of

shallow water on the reef and between it and the land.

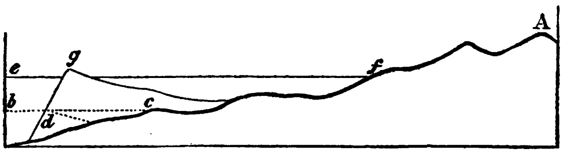
To explain the phenomena above described, Mr. Darwin supposes that the coral-forming polypi begin to build in water of a moderate depth, and, while they are yet at work, the bottom of the sea subsides gradually, so that the foundation of their edifice is carried downwards at the same time that they are raising the superstructure. If, therefore, the rate of subsidence be not too rapid, the growing coral will continue to build up to the surface; the mass always gaining in height above its original base, but remaining in other respects in the same position. Not so with the land: each inch lost is irreclaimably gone; as it sinks the water gains foot by foot on the shore, till in many cases the highest peak of the original island disappears. What was before land is then occupied by the lagoon, the position of the encircling coral remaining unaltered, with the exception of a slight contraction of its dimensions.

In this manner are encircling reefs and atolls produced; and in confirmation of his theory Mr. Darwin has pointed out examples which illustrate every intermediate state, from that of lofty islands, such as Otaheite, encircled by coral, to that of Gambier's group, where a few peaks only of land rise out of a lagoon, and, lastly, to the perfect atoll, having a lagoon several hundred feet deep, surrounded by a reef rising steeply from an unfathomed ocean.

If we embrace these views, it is clear, that in regions of growing coral a similar subsidence must give rise to barrier reefs along the shores of a continent. Thus suppose A (fig. 95.) to represent the north-east portion of Australia, and *b c* the ancient level of the sea, when

the coral reef *d* was formed. If the land sink so that it is submerged more and more, the sea must at

Fig. 95.



length stand at the level *e f*, the reef in the mean time having been enlarged and raised to the point *g*. The distance between the shore *f*, and the barrier reef *g*, is now much greater than originally between the shore *c*, and the reef *d*, and the longer the subsidence continues the farther will the coast of the mainland recede.

When the first edition of this work appeared in 1831, several years before Mr. Darwin had investigated the facts on which his theory is founded, I had come to the opinion that the land was subsiding at the bottom of those parts of the Pacific where atolls are numerous, although I failed to perceive that such a subsidence, if conceded, would equally solve the enigma as to the form both of annular and barrier reefs.

I shall cite the passage referred to, as published by me in 1831: — "It is a remarkable circumstance that there should be so vast an area in Eastern Oceanica, studded with minute islands, without one single spot where there is a wider extent of land than belongs to such islands as Otaheite, Owhyhee, and a few others, which either have been or are still the seats of active volcanos. If an equilibrium only were maintained between the upheaving and depressing force of earthquakes, large islands would very soon be formed in

the Pacific; for, in that case, the growth of limestone, the flowing of lava, and the ejection of volcanic ashes, would combine with the upheaving force to form new land.

"Suppose a shoal, 600 miles in length, to sink fifteen feet, and then to remain unmoved for a thousand years; during that interval the growing coral may again approach the surface. Then let the mass be re-elevated fifteen feet, so that the original reef is restored to its former position: in this case, the new coral formed since the first subsidence will constitute an island 600 miles long. An analogous result would have occurred if a lava current fifteen feet thick had overflowed the submerged reef. The absence, therefore, of more extensive tracts of land in the Pacific, seems to show that the amount of subsidence by earthquakes exceeds, in that quarter of the globe, at present, the elevation due to the same cause." *

Another proof also of subsidence derived from the structure of atolls, was pointed out by me in the following passage in all former editions. "The low coral islands of the Pacific," says Captain Beechey, "follow one general rule in having their windward side higher and more perfect than the other. At Gambier and Matilda islands this inequality is very conspicuous, the weather side of both being wooded, and of the former inhabited, while the other sides are from twenty to thirty feet under water; where, however, they may be perceived to be equally *narrow* and well defined. It is on the leeward side also that the entrances into the lagoons occur; and although they may sometimes be situated on a side that runs in the

* See Principles of Geol., 1st. ed. vol. ii. p. 296.

direction of the wind, as at Bow Island, yet there are none to windward." These observations of Captain Beechey accord with those which Captain Horsburgh, and other hydrographers, have made in regard to the coral islands of other seas. From this fortunate circumstance ships can enter and sail out with ease; whereas if the narrow inlets were to windward, vessels which once entered might not succeed for months in making their way out again. The well-known security of many of these harbours depends entirely on this fortunate peculiarity in their structure.

"In what manner is this singular conformation to be accounted for? The action of the waves is seen to be the cause of the superior elevation of some reefs on their windward sides, where sand and large masses of coral rock are thrown up by the breakers; but there is a variety of cases where this cause alone is inadequate to solve the problem; for reefs submerged at considerable depths, where the movements of the sea cannot exert much power, have, nevertheless, the same conformation, the leeward being much lower than the windward side.*

"I am informed by Captain King, that, on examining the reefs called Rowley Shoals, which lie off the north-west coast of Australia, where the east and west monsoons prevail alternately, he found the open side of one crescent-shaped reef, the Impérieuse, turned to the east, and of another, the Mermaid, turned to the west; while a third oval reef, of the same group, was entirely submerged. This want of conformity is exactly what we should expect, where the winds vary periodically.

* Voyage to the Pacific, &c., p. 189.

"It seems impossible to refer the phenomenon now under consideration to any original uniformity in the configuration of submarine volcanos, on the summits of which we may suppose the coral reefs to grow; for although it is very common for craters to be broken down on one side only, we cannot imagine any cause that should breach them all in the same direction. But the difficulty will, perhaps, be removed, if we call in another part of the volcanic agency — subsidence by earthquakes. Suppose the windward barrier to have been raised by the mechanical action of the waves to the height of two or three yards above the wall on the leeward side, and then the whole island to sink down a few fathoms, the appearances described would then be presented by the submerged reef. A repetition of such operations, by the alternate elevation and depression of the same mass (an hypothesis strictly conformable to analogy), might produce still greater inequality in the two sides, especially as the violent efflux of the tide has probably a strong tendency to check the accumulation of the more tender corals on the leeward reef; while the action of the breakers contributes to raise the windward barrier."*

Previously to my adverting to the signs above enumerated of a downward movement in the bed of the ocean, Dr. MacCulloch, Captain Beechey, and many other writers had shown that masses of recent coral had been laid dry at various heights above the sea-level, both in the Red Sea, the islands of the Pacific, and in the East and West Indies. After describing thirty-two coral islands in the Pacific, Captain Beechey mentioned that they were all formed of living coral

* See Principles of Geol. 1st. ed. vol. ii. p. 293.

except one, which, although of coral formation, was raised about seventy or eighty feet above the level of the sea, and was encompassed by a reef of living coral. It is called Elizabeth or Henderson's Island, and is five miles in length by one in breadth. It has a flat surface, and, on all sides, except the north, is bounded by perpendicular cliffs about fifty feet high, composed entirely of dead coral, more or less porous, honey-combed at the surface, and hardening into a compact calcareous mass, which possesses the fracture of secondary limestone, and has a species of millepore interspersed through it. These cliffs are considerably undermined by the action of the waves, and some of them appear on the eve of precipitating their superincumbent weight into the sea. Those which are less

Fig. 96.

Elizabeth, or Henderson's Island.

injured in this way present no alternate ridges or indication of the different levels which the sea might have occupied at different periods; but a smooth surface, as if the island, which has probably been raised by volcanic agency, had been forced up by one great subterraneous convulsion.* At the distance of a few hundred yards from this island, no bottom could be gained with 200 fathoms of line.

It will be seen, from the annexed sketch, communicated to me by Lieutenant Smith, of the Blossom, that the trees came down to the beach towards the centre

* Beechey's Voyage to the Pacific, &c., p. 46.

of the island; a break at first sight resembling the openings which usually lead into lagoons: but the trees stand on a steep slope, and no hollow of an ancient lagoon was perceived.

Beechey also remarks, that the surface of Henderson's Island is flat, and that in Queen Charlotte's Island, one of the same group, but under water, there was no lagoon, the coral having grown up every where to one level. The probable cause of this obliteration of the central basin or lagoon will be considered in the sequel.

That the bed of the Pacific and Indian oceans, where atolls are frequent, must have been sinking for ages, might be inferred, says Mr. Darwin, from simply reflecting on two facts; first, that the efficient coral-building zoophytes do not flourish in the ocean at a greater depth than 120 feet; and, secondly, that there are spaces occupying areas of many hundred thousand square miles, where all the islands consist of coral, and yet none of which rise to a greater height than may be accounted for by the action of the winds and waves on broken and triturated coral. Were we to take for granted that the floor of the ocean had remained stationary from the time when the coral began to grow, we should be compelled to assume that an incredible number of submarine mountains of vast height (for the ocean is always deep, and often unfathomable between the different atolls,) had all come to within 120 feet of the surface, and yet no one mountain had risen above water. But no sooner do we admit the theory of subsidence, than this great difficulty vanishes. However varied may have been the altitude of different islands, or the separate peaks

of particular mountain-chains, all may have been reduced to one uniform level by the gradual submergence of the loftiest points, and the additions made to the calcareous cappings of the less elevated summits as they subsided to great depths.

Assuming, then, that the presence of lagoon islands, and of encircling and barrier reefs, afford proofs of the sinking of the ground, and that skirting reefs and uplifted banks of shells and corals furnish evidence of the rising of the same, Mr. Darwin next arrived at the important generalization, that the Pacific and Indian seas, and some of the lands which border them, might be divided into areas of elevation and areas of subsidence, which occur alternately. Thus, if we commence with the western shores of South America, we find signs of recent elevation, not attested indeed by coral formations, which are wanting there, but by upraised banks of marine shells. Proceeding westward, we must then traverse a deep ocean without islands, until we come to a band of *atolls* and encircled islands, including the Dangerous and Society archipelagos, and constituting an area of subsidence more than 4000 miles long and 600 broad. Still farther, in the same direction, we reach the chain of islands to which the New Hebrides, Solomon, and New Ireland belong, where fringing reefs and masses of elevated coral indicate another area of upheaval. Again, to the westward of the New Hebrides we meet with the encircling reef of New Caledonia and the great Australian barrier, implying a second area of subsidence.

Having laid before the reader this brief analysis of Mr. Darwin's theory, I shall next endeavour to trace out some of the other natural consequences to which

it appears to me to lead.* It is clear that the form and structure of reefs will be greatly modified according to the direction and rate of the movement, as whether it has been upward or downward, always in one direction, or oscillatory, slow or rapid, intermittent or uniform.

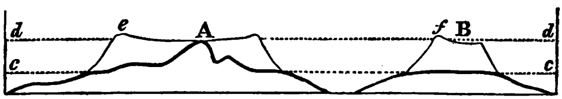
Subsidence.— When we consider that the space over which atolls are scattered in Polynesia and the Indian oceans, may be compared to the whole continent of Asia, we cannot but infer from analogy that the differences in level in so vast an area, amounted, before the beginning of any subsidence, to 5000, 10,000, or even a greater number of feet. Whatever was the difference in height between the loftiest and lowest of the original mountains on which the different atolls are based, that difference must represent the thickness of coral which has now reduced all of them to one level. Flinders, therefore, by no means exaggerated the volume of the limestone, which he conceived to have been the work of coral animals; he was merely mistaken as to the manner in which they were enabled to raise up reefs from the bottom of an unfathomed ocean.

If we reflect on the consequences of a downward movement, it will appear that, provided the bottom does not sink too fast to allow the zoophytes to build upwards at the same pace, the thickness of coral will be great in proportion to the rapidity of subsidence, so that if one area sinks two feet while another sinks one,

* I know not how far the conclusions deduced in the remainder of this chapter may agree with those at which Mr. Darwin has arrived, and which he will explain in detail in his forthcoming work on Coral Formations.

the mass of coral in the first area will be double that in the second. But where the downward movement has been uniform, the thickness of the limestone will be the same whether the reef originally encircled a shoal or a lofty island. Thus, for example, when the foundations of the atolls A, B (Fig. 97.) were laid, the sea being at the level *c*, A was an encircled island

Fig. 97.



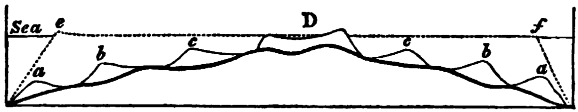
2000 feet high, and B a shoal only dry at low water; but the land having been sinking for centuries, so that the sea now stands at the level *d*, the mass of coral is of equal thickness, namely about 2000 feet, beneath the points *e* and *f*. It is in the centre only of the two atolls that there is a great comparative difference in the thickness of coral.

If the rate of subsidence be uniform and such as to carry down the bottom faster than the corals can raise it by their upward growth, there will then be no encircling reef or atoll, but the island or continent will be submerged more and more, having first become incrusted over with coralline limestone, which will form a dense or thin coating according as the movement has been slow or rapid.

On the other hand, if the motion be not uniform, and yet the ground sink upon the whole faster than the corals can grow upwards, there may be numerous rings of coral formed, as represented at *a*, *b*, *c* in the section (Fig. 98.), these rings marking the periods when the downward movement was slow enough to allow of

a considerable growth of coral, first at *a*, then at *b*, and then at *c*; the intervening spaces marking periods of rapid subsidence which only allowed time for the growth of a very thin crust (if any) of coral. At length, if the rate of sinking diminish, the small atoll D may be formed, whereas if the same land had gone down more slowly, that is to say, at such a rate as that the move-

Fig. 98.



ment never exceeded in vertical amount that which the growing coral can keep pace with, then, instead of the rings *a*, *b*, *c*, the large atoll *e f* would be raised on the same base.

On the other hand, if land be rising with an irregular or intermittent motion, rings of coral like those represented at *a*, *b*, *c* (Fig. 98.), might also be formed, the only difference being, that in that case the upper rings will be first produced at periods when the elevation proceeds slowly, and then the lower ones.

If the movement be both elevatory and uniform the shore will be constantly bordered by a fringing reef, and the surface of the land, as it rises from the sea, will be overspread with corals. This covering, however, will not in all likelihood remain continuous, because it will be exposed to the denuding action of the waves during upheaval, and after emergence may become concealed under lava or volcanic matter.

The island of Pulo Nias, off Sumatra, which is about 3000 feet high, is described by Dr. Jack as being overspread by coral and large shells of the *Chama* (*Tridacna*) *gigas*, which rest on quartzose and arena-

ceous rocks, at various levels from the sea-coast to the summit of the highest hills.*

Oscillations. — We may next consider the effects of an oscillatory movement like that of the ground on which stands the Temple of Serapis, near Naples, which has twice risen and twice subsided within the last 2000 years.† In former editions I stated, that if in a region of atolls the alternate upward and downward movements balance each other, large masses of coral will be raised above the level of the sea, and islands, such as Henderson's before mentioned, which is about sixty feet or more in height, will appear, or like the Tonga and Hapai isles, which stand from ten to thirty feet above the level of the water.

We learn from the description of Henderson's Island just alluded to, that an upraised mass of coral may present cliffs, undermined by the waves, and surrounded by a coral reef. In such cases, if oscillations be repeated, a most complicated structure must result, one reef serving as the nucleus of another, and calcareous sand, the produce of denudation, alternating with corals which will remain entire and in the position in which they have grown.

It was observed that Henderson's and Queen Charlotte's islands are flat-topped, and exhibit no traces of a lagoon. The former, although about sixty or seventy feet high, stands in the midst of a region of atolls, and exhibits, therefore, an instance of partial upheaval in an area of subsidence. We may presume that, after sinking for ages, it was at length upheaved. Now when the descending movement was relaxed and in the

* Geol. Trans., second series, vol. i. p. 397.

† See Vol. II. p. 399.

course of being converted into an ascending one, the ground would probably remain for a long season almost stationary, in which case the corals within the lagoon would build up to the surface, and reach the level already attained by those on the margin of the reef. In this manner the lagoon would be effaced, and the island acquire a flat summit.

Openings into the lagoons. — In the general description of atolls and encircling reefs, it was mentioned that there is almost always a deep narrow passage opening into the lagoon, or into the still water between the reef and the shore, which is kept open by the efflux of the sea as the tide goes down.

The origin of this channel must, according to the theory before advocated, be traced back to causes which were in action during the existence of the encircling reef, and when an island or mountain top rose within it, for such a reef precedes the atoll in the order of formation. Now in those islands in the Pacific, which are large enough to feed small rivers, there is generally an opening or channel in the surrounding coral reef at the point where the stream of fresh water enters the sea. The depth of these channels rarely exceeds twenty-five feet; and they may be attributed, says Captain Beechey, to the aversion of the lithophytes to fresh water, and to the probable absence of the mineral matter of which they construct their habitations.*

Mr. Darwin, however, is of opinion, that mud at the bottom of river-courses is more influential than the freshness of the water in preventing the growth of the polypi, for the walls which inclose the openings

* Voyage to the Pacific, &c., p. 194.

are perpendicular, and do not slant off gradually, as would be the case, if the nature of the element presented the only obstacle to the increase of the coral-building animals.

When a breach has thus been made in the reef, it will be prevented from closing up by the efflux of the sea at low tides; for it is sufficient that a reef should rise a few feet above low-water mark to cause the waters to collect in the lagoon at high tide, and when the sea falls, to rush out at one or more points where the reef happens to be lowest or weakest. This event is strictly analogous to that witnessed in our estuaries, where a body of salt water accumulated during the flow issues with great velocity at the ebb of the tide, and scours out or keeps open a deep passage through the bar, which is almost always formed at the mouth of a river. At first there are probably many openings, but the growth of the coral tends to obstruct all those which do not serve as the principal channels of discharge; so that their number is gradually reduced to a few, and often finally to one.

Size of atolls and barrier reefs. — In regard to the dimensions of atolls, it was stated that some of the smallest observed by Beechey in the Pacific, were only a mile in diameter. If their external slope under water equals upon an average an angle of 45°, then would such an atoll at the depth of half a mile, or 2640 feet, have a diameter of two miles. Hence it would appear, that there must be a tendency in every atoll to grow smaller, except in those cases where oscillations of level enlarge the base on which the coral grows, by throwing down a talus of detrital matter all round the original cone of limestone. We have already shown, in the explanation of the diagram

(Fig. 98.), that if the rate of subsidence be accelerated at times, the dimensions of the encircling reef will be circumscribed. If, in spite of this tendency, we find so many lagoon islands of enormous size, it proves how uniform as well as slow has been the downward movement.

Bow Island is described by Captain Beechey as 70 miles in circumference, and 30 in its greatest diameter, and some of the Maldivas are said to be twice as large. The base of such atolls must be considerably larger, but we cannot calculate from the dimensions of the base, if known, what may have been the height of the island now changed into an atoll. In other words, we cannot estimate the thickness of the coral which has accumulated, for the inclination of the surface of an island from its highest peak to the shore varies greatly, and follows no fixed rule. Suppose, for example, we take the two largest of the Canaries, Fuertaventura, and the Peak of Teneriffe; the former is about 80 miles long by about 20 broad, and somewhat less than 2000 feet high, while Teneriffe is about 50 miles long, and its greatest breadth about 30 miles, its height being above 2 miles. If, therefore, both of these had been situated in the coral region of the Pacific, the smallest must have sunk about 11,000 feet, and the largest only 2000 feet, in order to be converted into atolls, in which case they might resemble in size some of the circular reefs now existing.

As the shore of an island or continent which is subsiding will recede from a coral reef at a slow or rapid rate, according as the surface of the land has a steep or gentle slope, we cannot measure the thickness of the coral by its distance from the coast; yet, as a general rule, those reefs which are farthest from the

land imply the greatest amount of subsidence. We learn from Flinders, that the barrier reef of north-eastern Australia is in some places seventy miles from the mainland, and it should seem that a calcareous formation is there in progress 1000 miles long from north to south, with a breadth varying from twenty to seventy miles. It may not, indeed, be continuous over this vast area, for doubtless innumerable islands have been submerged one after another between the reef and mainland, like some which still remain, as, for example, Murray's Islands, lat. 9° 54′ S. We are also told that some parts of the gulf inclosed within the barrier are 400 feet deep, so that the efficient corals cannot be growing there, and in other parts of it islands appear encircled by reefs.

Structure and Stratification. — It is curious to reflect that if the bottom of the equatorial seas where atolls abound, were upraised and laid dry, we should behold mountain-peaks and ridges composed fundamentally of volcanic, granitic, and other rocks, on which tabular masses of limestone would repose. Some of these calcareous cappings would be continuous over an area three miles, others above 300 miles in circumference, while their thickness might vary from 1000 to 10,000 feet, or more. They would consist principally of corals and shells, in some places entire, in others broken. In the lower regions of the same continent, and between the high table-lands or mountain-ridges, there would often be no contemporary deposits, or, where exceptions occurred to this rule, the calcareous strata would differ in their nature as much as in the species of fossils which they inclosed, from the tabular masses of coral. It has been observed that the softer corals, when they decompose in the lagoon, are resolved

into a white mud, which when dried is undistinguishable from common chalk.* This fine sediment must often be carried by the waves and currents to great distances, and sinking may envelope such zoophytes and brachiopodous mollusca, as inhabit deep water. Thus a recent cretaceous formation may now be in progress in many parts of the Pacific and Indian oceans.

Captain Beechey remarks, in a passage before cited, that the dead coral, which has been raised to the height of fifty feet and upwards in Henderson's Island, is more or less porous, and honey-combed at the surface, and hardening into a compact calcareous substance within. The same rock, he says, possesses the fracture of secondary limestone, and has a species of millepore dispersed through it.† The accounts of other observers attest, in like manner, the tendency of recent coral to become converted into solid limestone, for the percolating waters seem always ready to deposit carbonate of lime in the interstices. A certain degree of stratification will usually be imparted to coralline formations by the arrangement of particular species of zoophytes and testacea in particular beds. In other situations, the sand-pebbles and earthy particles brought into the sea by rivers, will cause divisions of a more marked character. If there has been an active volcano on the neighbouring land, showers of cinders or sheets of lava may interrupt suddenly the growth of one coral reef, and afterwards serve as a foundation for another. An example of this kind is seen in the Isle of France, where a bed of

* Lieut. Nelson, Geol. Trans., second series, vol. v.

† Beechey, vol. i. p. 45.

coral, ten feet thick, intervenes between two currents of lava;* and in the West Indies, in the island of Dominica, Maclure observes, that "a bed of coral and madrepore limestone, with shells, lies horizontally on a bed of cinders, about 200 or 300 feet above the level of the sea, at Rousseau, and is covered with cinders to a considerable height." †

Lime, whence derived.— A modern writer has attempted to revive the theory of some of the earlier geologists, that all limestones have originated in organized substances. If we examine, he says, the quantity of limestone in the primary strata, it will be found to bear a much smaller proportion to the siliceous and argillaceous rocks than in the secondary; and this may have some connexion with the rarity of testaceous animals in the ancient ocean. He further infers, that in consequence of the operations of animals, "the quantity of calcareous earth deposited in the form of mud or stone is always increasing; and that, as the secondary series far exceeds the primary in this respect, so a third series may hereafter arise from the depths of the sea, which may exceed the last in the proportion of its calcareous strata." ‡

If these propositions went no farther than to suggest that every particle of lime that now enters into the crust of the globe may possibly in its turn have been subservient to the purposes of life, by entering into the composition of organized bodies, I should not deem

* De la Bêche, Geol. Man., p. 142. Quoy and Gaimard, Ann. des Sci. Nat., tome vi.

† Observ. on Geology of the West Indian Islands, Journ. of Sci., &c. No. x. p. 318.

‡ MacCulloch's Syst. of Geol., vol. i. p. 219.

the speculation improbable; but, when it is hinted that lime may be an animal product combined by the powers of vitality from some simple elements, I can discover no sufficient grounds for such an hypothesis, and many facts militate against it.

If a large pond be made, in almost any soil, and filled with rain water, it may usually become tenanted by testacea; for carbonate of lime is almost universally diffused in small quantities. But if no calcareous matter be supplied by waters flowing from the surrounding high grounds, or by springs, no tufa or shell-marl are formed. The thin shells of one generation of mollusks decompose, so that their elements afford nutriment to the succeeding races; and it is only where a stream enters a lake, which may introduce a fresh supply of calcareous matter, or where the lake is fed by springs, that shells accumulate and form marl.

All the lakes in Forfarshire which have produced deposits of shell-marl have been the sites of springs, which still evolve much carbonic acid, and a small quantity of carbonate of lime. But there is no marl in Loch Fithie, near Forfar, where there are *no springs*, although that lake is surrounded by these calcareous deposits, and although, in every other respect, the site is favourable to the accumulation of aquatic testacea.

We find those charæ which secrete the largest quantity of calcareous matter in their stems to abound near springs impregnated with carbonate of lime. We know that, if the common hen be deprived altogether of calcareous nutriment, the shells of her eggs will become of too slight a consistency to protect the contents; and some birds eat chalk greedily during the breeding season.

If, on the other hand, we turn to the phenomena of

inorganic nature, we observe that, in volcanic countries, there is an enormous evolution of carbonic acid, either free, in a gaseous form, or mixed with water; and the springs of such districts are usually impregnated with carbonate of lime in great abundance. No one who has travelled in Tuscany, through the region of extinct volcanos and its confines, or who has seen the map constructed by Targioni (1827), to show the principal sites of mineral springs, can doubt, for a moment, that, if this territory was submerged beneath the sea, it might supply materials for the most extensive coral reefs. The importance of these springs is not to be estimated by the magnitude of the rocks which they have thrown down on the slanting sides of hills, although of these alone large cities might be built, nor by a coating of travertin that covers the soil in some districts for miles in length. The greater part of the calcareous matter passes down in a state of solution to the sea, and in all countries the rivers which flow from chalk and other marly and calcareous rocks carry down vast quantities of lime into the ocean. Lime is also one of the component parts of augite and other volcanic and hypogene minerals, and when these decompose is set free, and may then find its way in a state of solution to the sea.

The lime, therefore, contained generally in sea-water, and secreted so plentifully by the testacea and corals of the Pacific, may have been derived either from springs rising up in the bed of the ocean, or from rivers fed by calcareous springs, or impregnated with lime derived from disintegrated rocks, both volcanic and hypogene. If this be admitted, the greater proportion of limestone in the more modern formations, as compared to the most ancient, will be explained, for

springs in general hold no argillaceous, and but a small quantity of siliceous matter in solution, but they are continually subtracting calcareous matter from the inferior rocks. The constant transfer, therefore, of carbonate of lime from the lower or older portions of the earth's crust to the surface, must cause at all periods, and throughout an indefinite succession of geological epochs, a preponderance of calcareous matter in the newer as contrasted with the older formations.

Concluding Remarks. — In the concluding chapters of the first book, I examined in detail a great variety of arguments which have been adduced to prove the distinctness of the state of the earth's crust at remote and recent epochs. Among other supposed proofs of this distinctness, the dearth of calcareous matter, in the ancient rocks above adverted to, might have been considered. But it would have been endless to enumerate all the objections urged against those geologists who represent the course of nature at the earliest periods as resembling in all essential circumstances the state of things now established. We have seen that, in opposition to this doctrine, a strong desire has been manifested to discover in the ancient rocks the signs of an epoch when the planet was uninhabited, and when its surface was in a chaotic condition and uninhabitable. The opposite opinion, indeed, that the oldest of the rocks now visible may be the last monuments of an antecedent era in which living beings may already have peopled the land and water, has been declared to be equivalent to the assumption that there never was a beginning to the present order of things.

With equal justice might an astronomer be accused of asserting that the works of creation extended

throughout *infinite* space, because he refuses to take for granted that the remotest stars now seen in the heavens, are on the utmost verge of the material universe. Every improvement of the telescope has brought thousands of new worlds into view; and it would, therefore, be rash and unphilosophical to imagine that we already survey the whole extent of the vast scheme, or that it will ever be brought within the sphere of human observation.

But no argument can be drawn from such premises in favour of the infinity of the space that has been filled with worlds; and if the material universe has any limits, it then follows, that it must occupy a minute and infinitesimal point in infinite space.

So if, in tracing back the earth's history, we arrive at the monuments of events which may have happened millions of ages before our times, and if we still find no decided evidence of a commencement, yet the arguments from analogy in support of the probability of a beginning remain unshaken; and if the past duration of the earth be finite, then the aggregate of geological epochs, however numerous, must constitute a mere moment of the past, a mere infinitesimal portion of eternity.

It has been argued, that, as the different states of the earth's surface, and the different species by which it has been inhabited, have all had their origin, and many of them their termination, so the entire series may have commenced at a certain period. It has also been urged, that, as we admit the creation of man to have occurred at a comparatively modern epoch — as we concede the astonishing fact of the first introduction of a moral and intellectual being — so also we may conceive the first creation of the planet itself.

I am far from denying the weight of this reasoning from analogy; but, although it may strengthen our conviction, that the present system of change has not gone on from eternity, it cannot warrant us in presuming that we shall be permitted to behold the signs of the earth's origin, or the evidences of the first introduction into it of organic beings. We aspire in vain to assign limits to the works of creation in *space*, whether we examine the starry heavens, or that world of minute animalcules which is revealed to us by the microscope. We are prepared, therefore, to find that in *time* also the confines of the universe lie beyond the reach of mortal ken. But in whatever direction we pursue our researches, whether in time or space, we discover every where the clear proofs of a Creative Intelligence, and of His foresight, wisdom, and power.

As geologists, we learn that it is not only the present condition of the globe which has been suited to the accommodation of myriads of living creatures, but that many former states also have been adapted to the organization and habits of prior races of beings. The disposition of the seas, continents, and islands, and the climates, have varied; the species likewise have been changed; and yet they have all been so modelled, on types analogous to those of existing plants and animals, as to indicate, throughout, a perfect harmony of design and unity of purpose. To assume that the evidence of the beginning or end of so vast a scheme lies within the reach of our philosophical inquiries, or even of our speculations, appears to be inconsistent with a just estimate of the relations which subsist between the finite powers of man and the attributes of an Infinite and Eternal Being.

GLOSSARY

OF GEOLOGICAL AND OTHER SCIENTIFIC TERMS USED IN THIS WORK.

Acephalous. The Acephala are that divsion of mulluscous animals which, like the oyster and scallop, are without heads. The class Acephala of Cuvier comprehends many genera of animals with bivalve shells, and a few which are devoid of shells. *Etym.*, *a*, *a*, without, and *κεφαλη*, *cephale*, the head.

Acidulous. Slightly acid.

Adipocire. A substance apparently intermediate between fat and wax, into which dead animal matter is converted when buried in the earth, and in a certain stage of decomposition. *Etym.*, *adeps*, fat, and *cera*, wax.

Albite. See "Felspar."

Alembic. An apparatus for distilling.

Algæ. An order or division of the cryptogamic class of plants. The whole of the sea-weeds are comprehended under this division, and the application of the term in this work is to marine plants. *Etym.*, *alga*, sea-weed.

Alluvial. The adjective of alluvium, which see.

Alluvion. Synonymous with alluvium, which see.

Alluvium. Earth, sand, gravel, stones, and other transported matter which has been washed away and thrown down by rivers, floods, or other causes, upon land not *permanently* submerged beneath the waters of lakes or seas. *Etym.*, *alluo*, to wash upon, or *alluvio*, an inundation.

Alum-stone, Alumen, Aluminous. Alum is the base of pure clay, and strata of clay are often met with containing much iron-pyrites. When the latter substance decomposes, sulphuric acid is produced, which unites with the aluminous

earth of the clay to form sulphate of alumine, or common alum. Where manufactories are established for obtaining the alum, the indurated beds of clay employed are called Alum-stone.

AMMONITE. An extinct and very numerous genus of the order of molluscous animals called Cephalopoda, allied to the modern genus Nautilus, which inhabited a chambered shell, curved like a coiled snake. Species of it are found in all geological periods of the secondary strata; but they have not been seen in the tertiary beds. They are named from their resemblance to the horns on the statues of Jupiter Ammon.

AMORPHOUS. Bodies devoid of regular form. *Etym.*, *α*, *a*, without, and μορφη, *morphe*, form.

AMYGDALOID. One of the forms of the Trap-rocks, in which agates and simple minerals appear to be scattered like almonds in a cake. *Etym.*, αμυγδαλα, *amygdala*, an almond.

ANALCIME. A simple mineral of the Zeolite family, also called Cubizite, of frequent occurrence in the Trap-rocks.

ANALOGUE. A body that resembles or corresponds with another body. A recent shell of the same species as a fossil shell is the analogue of the latter.

ANOPLOTHERIUM. A fossil extinct duadruped belonging to the order Pachydermata, resembling a pig. It has received its name because the animal must have been singularly wanting in means of defence, from the form of its teeth and the absence of claws, hoofs, and horns. *Etym.*, ανοπλος, *anoplos*, unarmed, and θηριον, *therion*, a wild beast.

ANTAGONIST POWERS. Two powers in nature, the action of the one counteracting that of the other, by which a kind of equilibrium or balance is maintained, and the destructive effect prevented that would be produced by one operating without a check.

ANTENNÆ. The articulated horns with which the heads of insects are invariably furnished.

ANTHRACITE. A shining substance like black-lead; a species of mineral charcoal. *Etym.*, ανθραξ, *anthrax*, coal.

ANTHRACOTHERIUM. A name given to an extinct quadruped, supposed to belong to the Pachydermata, the bones of which were first found in lignite and coal of the tertiary strata. *Etym.*, ανθραξ, *anthrax*, coal, and θηριον, *therion*, wild beast.

ANTHROPOMORPHOUS. Having a form resembling the human.

Etym., ανθρωπος, *anthropos*, a man, and μορφη, *morphe*, form.

ANTISEPTIC. Substances which prevent corruption in animal and vegetable matter, as common salt does, are said to be antiseptic. *Etym.*, αντι, *against*, and σηπω, *sepo*, to putrify.

ARENACEOUS. Sandy. *Etym.*, *arena*, sand.

ARGILLACEOUS. Clayey, composed of clay. *Etym.*, *argilla*, clay.

ARRAGONITE. A simple mineral, a variety of carbonate of lime, so called from having been first found in Arragon, in Spain.

ATOLLS. Coral islands of an annular form, or consisting of a circular strip or ring of coral surrounding a central lagoon.

AUGITE. A simple mineral of a dark green, or black colour, which forms a constituent part of many varieties of volcanic rocks. Name applied by Pliny to a particular mineral, from the Greek ἀυγη, *auge*, lustre.

AVALANCHES. Masses of snow which, being detached from great heights in the Alps, acquire enormous bulk by fresh accumulations as they descend; and when they fall into the valleys below often cause great destruction. They are also called *lavanges*, and *lavanches*, in the dialects of Switzerland.

BASALT. One of the most common varieties of the Trap-rocks. It is a dark green or black stone, composed of augite and felspar, very compact in texture, and of considerable hardness, often found in regular pillars of three or more sides called basaltic columns. Remarkable examples of this kind are seen at the Giant's Causeway, in Ireland, and at Fingal's Cave, in Staffa, one of the Hebrides. The term is used by Pliny, and is said to come from *basal*, an Æthiopian word signifying iron. The rock often contains much iron.

"BASIN" of Paris, "BASIN" of London. Deposits lying in a hollow or trough, formed of older rock; sometimes used in geology almost synonymously with "formations," to express the deposits lying in a certain cavity or depression in older rocks.

BELEMNITE. An extinct genus of the order of molluscous animals called Cephalopoda, having a long, straight, and chambered conical shell. *Etym.*, βελεμνον *belemnon*, a dart.

BITUMEN. Mineral pitch, of which the tar-like substance which

is often seen to ooze out of the Newcastle coal when on the fire, and which makes it cake, is a good example. *Etym.*, *bitumen*, pitch.

BITUMINOUS SHALE. An argillaceous shale, much impregnated with bitumen, which is very common in the Coal Measures.

BLENDE. A metallic ore, a compound of the metal zinc with sulphur. It is often found in brown shining crystals; hence its name among the German miners, from the word *blenden*, to dazzle.

BLUFFS. High banks presenting a precipitous front to the sea or a river. A term used in the United States of North America.

BOTRYOIDAL. Resembling a bunch of grapes. *Etym.*, βοτρυς, *botrys*, a bunch of grapes, and ειδος, *eidos*, form.

BOULDERS. A provincial term for large rounded blocks of stone lying on the surface of the ground, or sometimes imbedded in loose soil, different in composition from the rocks in their vicinity, and which have been therefore transported from a distance.

BRECCIA. A rock composed of angular fragments connected together by lime or other mineral substance. An Italian term.

CALC SINTER. A German name for the deposits from springs holding carbonate of lime in solution — petrifying springs. *Etym.*, *kalk*, lime *sintern*, to drop.

CALCAIRE GROSSIER. An extensive stratum, or rather series of strata, found in the Paris Basin, belonging to the Eocene tertiary period. *Etym.*, *calcaire*, limestone, and *grossier*, coarse.

CALCAREOUS ROCK. Limestone. *Etym.*, *calx*, lime.

CALCAREOUS SPAR. Crystallized carbonate of lime.

CALCEDONY. A siliceous simple mineral, uncrystallized.— Agates are partly composed of calcedony.

CARBON. An undecomposed inflammable substance, one of the simple elementary bodies. Charcoal is almost entirely composed of it. *Etym.*, *carbo*, coal.

CARBONATE of LIME. Lime combines with great avidity with carbonic acid, a gaseous acid only obtained fluid when united with water, — and all combinations of it with other substan-

ces are called *Carbonates*. All limestones are carbonates of lime, and quick lime is obtained by driving off the carbonic acid, by heat.

CARBONATED SPRINGS. Springs of water, containing carbonic acid gas. They are very common, especially in volcanic countries; and sometimes contain so much gas, that if a little sugar be thrown into the water it effervesces like soda-water.

CARBONIC ACID GAS. A natural gas which often issues from the ground, especially in volcanic countries. *Etym.*, *carbo*, coal; because the gas is obtained by the slow burning of charcoal.

CARBONIFEROUS. A term usually applied, in a technical sense, to an ancient group of secondary strata; but any bed containing coal may be said to be carboniferous. *Etym.*, *carbo*, coal, and *fero*, to bear.

CATACLYSM. A deluge. *Etym.*, *κατακλυζω*, *catacluzo*, to deluge.

CEPHALOPODA. A class of molluscous animals, having their organs of motion arranged round their head. *Etym.*, *κεφαλη*, *cephale*, head, and *ποδα*, *poda*, feet.

CETACEA. An order of vertebrated mammiferous animals inhabiting the sea. The whale, dolphin, and narwal are examples. *Etym.*, *cete*, whale.

CHALK. A white earthy limestone, the uppermost of the secondary series of strata.

CHERT. A siliceous mineral, nearly allied to calcedony and flint, but less homogeneous and simple in texture. A gradual passage from chert to limestone is not uncommon.

CHLORITIC SAND. Sand colored green by an admixture of the simple mineral chlorite. *Etym.*, *χλωρος*, *chloros*, green.

CLEAVAGE. Certain rocks, usually called Slate-rocks, may be cleaved into an indefinite number of thin laminæ which are parallel to each other, but which are generally not parallel to the planes of the true strata or layers of deposition. The planes of cleavage, therefore, are distinguishable from those of stratification.

CLINKSTONE, called also phonolite, a felspathic rock of the trap family, usually fissile. It is sonorous when struck with a hammer, whence its name.

Coal Formation. This term is generally understood to mean the same as the Coal Measures, or Carboniferous group.

Coleoptera. An order of insects (Beetles) which have four wings, the upper pair being crustaceous and forming a shield. *Etym.*, κολεος, *coleos*, a sheath, and πτερον, *pteron*, a wing.

Conformable. When the planes of one set of strata are generally parallel to those of another set which are in contact they are said to be conformable. Thus the set *a*, *b*, Fig. 99.

Fig. 99.

rest conformably on the inferior set *c*, *d*; but *c*, *d* rest unconformably on E.

Congeners. Species which belong to the same genus.

Conglomerate, or Puddingstone. Rounded water-worn fragments of rock or pebbles, cemented together by another mineral substance, which may be of a siliceous, calcareous, or argillaceous nature. *Etym.*, *con*, together, *glomero* to heap.

Coniferæ. An order of plants which, like the fir and pine, bear cones or tops in which the seeds are contained. *Etym.*, *conus*, cone, and *fero*, to bear.

Cosmogony, Cosmology. Words synonymous in meaning, applied to speculations respecting the first origin or mode of creation of the earth. *Etym.*, κοσμος, *kosmos*, the world, and γονη, *gonee*, generation, or λογος, *logos*, discourse.

Crag. A provincial name in Norfolk and Suffolk for certain tertiary deposits usually composed of sand with shells, belonging to the Older Pliocene period.

Crater. The circular cavity at the summit of a volcano, from which the volcanic matter is ejected. *Etym.*, *crater*, a great cup or bowl.

Cretaceous. Belonging to chalk. *Etym.*, *creta*, chalk.

Crop Out. A miner's mineral surveyor's term, to express the rising up or exposure at the surface of a stratum or series of strata.

Crust of the Earth. See "Earth's crust."

Crustacea. Animals having a shelly coating or crust which

they cast periodically. Crabs, shrimps, and lobsters, are examples.

CRYPTOGAMIC. A name applied to a class of plants, such as ferns, mosses, sea-weeds, and fungi, in which the fructification or organs of reproduction are concealed. *Etym.*, κρυπτος, *kryptos*, concealed, and γαμος, *gamos*, marriage.

CRYSTALS. Simple minerals are frequently found in regular forms, with facets like the drops of cut glass of chandeliers. Quartz being often met with in rocks in such forms, and beautifully transparent like ice, was called *rock-crystal*, κρυσταλλος, *crystallos*, being Greek for ice. Hence the regular *forms* of other minerals are called crystals, whether they be clear or opake.

CRYSTALLIZED. A mineral which is found in regular forms or crystals is said to be crystallized.

CRYSTALLINE. The internal texture which regular crystals exhibit when broken, or a confused assemblage of ill-defined crystals. Loaf-sugar and statuary-marble have a *crystalline* texture. Sugar-candy and calcareous spar are crystallized.

CUPRIFEROUS. Copper-bearing. *Etym.*, *cuprum*, copper, and *fero*, to bear.

CYCADEÆ. An order of plants which are natives of warm climates, mostly tropical, although some are found at the Cape of Good Hope. They have a short stem, surmounted by a peculiar foliage, termed pinnated fronds by botanists, which spreads in a circle. The term is derived from κυκας, *cycas*, a name applied by the ancient Greek naturalist Theophrastus to a palm.

CYPERACEÆ. A tribe of plants answering to the English sedges; they are distinguished from grasses by their stems being solid, and generally triangular, instead of being hollow and round. Together with *gramineæ* they constitute what writers on botanical geography often call *glumaceæ*.

DEBACLE. A great rush of waters, which, breaking down all opposing barriers, carries forward the broken fragments of rocks, and spreads them in its course. *Etym.*, *débacler*, French, to unbar, to break up as a river does at the cessation of a long-continued frost.

DELTA. When a great river, before it enters the sea, divides into

separate streams, they often diverge and form two sides of a triangle, the sea being the base. The land included by the three lines, and which is invariably alluvial, was first called, in the case of the Nile, a delta, from its resemblance to the letter of the Greek alphabet which goes by that name Δ. Geologists apply the term to alluvial land formed by a river at its mouth, without reference to its precise shape.

DENUDATION. The carrying away by the action of running water of a portion of the solid materials of the land, by which inferior rocks are laid bare. *Etym.*, *denudo*, to lay bare.

DEOXIDIZED, DEOXIDATED. Deprived of oxygen. Disunited from oxygen.

DESICCATION. The act of drying up. *Etym.*, *desicco*, to dry up.

DETRITUS. Matter worn or rubbed off from rocks. *Etym.*, *de*, from, and *tero*, to rub.

DICOTYLEDONOUS. A grand division of the vegetable kingdom, founded on the plant having two *cotyledons*, or seed-lobes. *Etym.*, δις, *dis*, double κοτυληδον, cotyledon.

DIKES. When a mass of the unstratified or igneous rocks, such as granite, trap, and lava, appears as if injected into a rent in the stratified rocks, cutting across the strata, it forms a dike. They are sometimes seen running along the ground, and projecting, like a wall, from the softer strata on both sides of them having wasted away; whence they were first called in the north of England and in Scotland *dikes*, a provincial name for wall. It is not easy to draw the line between dikes and veins. The former are generally of larger dimensions, and have their sides parallel for considerable distances; while veins have generally many ramifications, and these often thin away into slender threads.

DILUVIUM. Those accumulations of gravel and loose materials which, by some geologists, are said to have been produced by the action of a diluvian wave or deluge sweeping over the surface of the earth. *Etym.*, *diluvium*, deluge.

DIP. When a stratum does not lie horizontally, but is inclined, it is said to *dip* towards some point of the compass, and the angle it makes with the horizon is called the angle of dip or inclination.

DIPTERA. An order of insects, comprising those which have

only two wings. *Etym.*, δις, *dis*, double, and πτερον, *pteron*, wing.

DOLERITE. One of the varieties of the Trap-rocks, composed of augite and felspar.

DOLOMITE. A crystalline limestone, containing magnesia as a constituent part. Named after the French geologist Dolomieu.

DUNES. Low hills of blown sand that skirt the shores of Holland, England, Spain, and other countries.

EARTH'S CRUST. Such superficial parts of our planet as are accessible to human observation.

ECPYROSIS. A Greek term for a destruction by fire.

ELYTRA. The wing-sheaths, or upper crustaceous membranes, which form the superior wings in the tribe of beetles. They cover the body, and protect the true membranous wing. *Etym.*, ελυτρον, *elytron*, a sheath.

ENTOMOSTRACA. Cuvier's second section of Crustacea; so called from their relationship to insects. *Etym.*, εντομα, *entoma*, insects.

EOCENE. A name given to the lowest division of the tertiary strata, containing an extremely small per-centage of living species amongst its fossil shells, which indicate the first commencement or dawn of the existing state of the animate creation. *Etym.*, ηως, *eos*, aurora or the dawn, and καινος, *kainos*, recent.

ESCARPMENT. The abrupt face of a ridge of high land. *Etym.*, *escarper*, French, to cut steep.

ESTUARIES. Inlets of the land, which are entered both by rivers and the tides of the sea. Thus we have the estuaries of the Thames, Severn, Tay, &c. *Etym.*, *æstus*, the tide.

EXPERIMENTUM CRUCIS. A decisive experiment, so called, because, like a cross or direction post, it directs men to true knowledge; or, as some explain it, because it is a kind of torture whereby the nature of the thing is extorted, as it were, by violence.

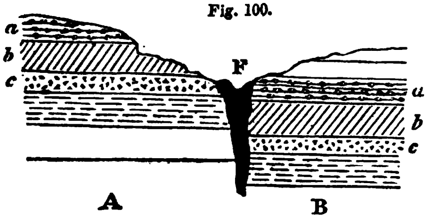
EXUVIÆ. Properly speaking, the transient parts of certain animals, which they put off or lay down to assume new ones, as serpents and caterpillars shift their skins; but in geology it refers not only to the cast-off coverings of animals, but to

fossil shells and other remains which animals have left in the strata of the earth. *Etym.*, *exuere*, to put off or divest.

FALUNS. A French provincial name for some tertiary strata abounding in shells in Touraine, which resemble in lithological characters the "Crag" of Norfolk and Suffolk.

FAULT, in the language of miners, is the sudden interruption of the continuity of strata in the same plane, accompanied by a crack or fissure, varying in width from a mere line to several feet, which is generally filled with broken stone, clay, &c.

Fig. 100.



The strata *a*, *b*, *c*, &c., must at one time have been continuous; but a fracture having taken place at the fault F, either by the upheaving of the portion A, or the sinking of the portion B, the strata were so displaced that the bed *a* in B is many feet lower than the same bed *a* in the portion A.

FAUNA. The various kinds of animals peculiar to a country constitute its FAUNA, as the various kinds of plants constitute its FLORA. The term is derived from the FAUNI, or rural deities, in Roman mythology.

FELSPAR. A simple mineral, which, next to quartz, constitutes the chief material of rocks. The white angular portions in granite are felspar. This mineral always contains some alkali in its composition. In *common felspar* the alkali is potash; in another variety, called Albite or Cleavlandite, it is soda. Glassy felspar is a term applied when the crystals have a considerable degree of transparency. *Compact* felspar is a name of more vague signification. The substance so called appears to contain both potash and soda.

FELSPATHIC. Of or belonging to felspar.

FERRUGINOUS. Any thing containing iron. *Etym.*, *ferrum*, iron.

FLOETZ ROCKS. A German term applied to the secondary strata

by the geologists of that country, because these rocks were supposed to occur most frequently in flat horizontal beds. *Etym.*, *flötz*, a layer or stratum.

FLORA. The various kinds of trees and plants found in any country constitute the FLORA of that country in the language of botanists.

FLUVIATILE. Belonging to a river. *Etym.*, *fluvius*, a river.

FORAMINIFERA. A name given by D'Orbigny to a family of microscopic shells. Their different chambers are united by a small perforation or *foramen*. Recent observation has shown that some at least are not cephalopoda, as D'Orbigny supposed.

FORMATION. A group, whether of alluvial deposits, sedimentary strata, or igneous rocks, referred to a common origin or period.

FOSSIL. All minerals were once called fossils, but geologists now use the word only to express the remains of animals and plants found buried in the earth *Etym.*, *fossilis*, any thing that may be dug out of the earth.

FOSSILIFEROUS. Containing organic remains.

GALENA. A metallic ore, a compound of lead and sulphur. It has often the appearance of highly polished lead. *Etym.*, γαλεω, *galeo*, to shine.

GARNET. A simple mineral, generally of a deep red colour, crystallized; most commonly met with in mica slate, but also in granite and other igneous rocks.

GASTEROPODS. A division of the Testacea, in which, as in the limpet, the foot is attached to the body. *Etym.*, γαστηρ, *gaster*, belly, and ποδα, *poda*, feet.

GAULT. A provincial name in the east of England for a series of beds of clay and marl, the geological position of which is between the Upper and Lower Green-sand.

GAVIAL. A kind of crocodile found in India.

GEM, or GEMMULE, from the Latin *gemma*, a bud. The term, applied to zoophytes, means a young animal not confined within an envelope or egg.

GEOLOGY, GEOGNOSY. Both mean the same thing; but with an unnecessary degree of refinement in terms, it has been proposed to call our description of the structure of the earth

geognosy (*Etym*, $\gamma\epsilon\alpha$, *gea*, earth, and $\gamma\iota\nu\omega\sigma\kappa\omega$ *ginosco*, to know), and our theoretical speculations as to its formation *geology* (*Etym*., $\gamma\epsilon\alpha$, and $\lambda o\gamma o\varsigma$, *logos*, a discourse).

GLACIER. Vast accumulations of ice and hardened snow in the Alps and other lofty mountains. *Etym*., *glace*, French for ice.

GLACIS. A term borrowed from the language of fortification, where it means an easy insensible slope or declivity, less steep than a *talus*, which see.

GNEISS. A stratified primary rock, composed of the same materials as granite, but having usually a larger proportion of mica and a laminated texture. The word is a German miner's term.

GRAMINEÆ. The order of plants to which grasses belong. *Etym*., *gramen*, grass.

GRANITE. An unstratified or igneous rock, generally found inferior to or associated with the oldest of the stratified rocks, and sometimes penetrating them in the form of dikes and veins. It is usually composed of three simple minerals, felspar, quartz, and mica, and derives its name from having a coarse *granular* structure; *granum*, Latin for grain. Westminster, Waterloo, and London bridges, and the paving-stones in the carriage-way of the London streets, afford good examples of the most common varieties of granite.

GREENSAND. Beds of sand, sandstone, limestone, belonging to the Cretaceous Period. The name is given to these beds because they often, but not always, contain an abundance of green earth or chlorite scattered through the substance of the sandstone, limestone, &c.

GREENSTONE. A variety of trap, composed of hornblende and felspar.

GREYWACKE. *Grauwacke*, a German name, generally adopted by geologists for some of the most ancient fossiliferous strata. The rock is very often of a grey colour; hence the name, *grau*, being German for grey, and *wacke*, being a provincial miner's term.

GRIT. A provincial name for a coarse-grained sand-stone.

GYPSUM. A mineral composed of lime and sulphuric acid, hence called also *sulphate of lime*. Plaster and stucco are obtained by exposing gypsum to a strong heat. It is found so abun-

dantly near Paris that plaster of Paris is a common term in this country for the white powder of which casts are made. The term is used by Pliny for a stone used for the same purposes by the ancients. The derivation is unknown.

GYPSEOUS, of or belonging to gypsum.

GYROGONITES. Bodies found in freshwater deposits, originally supposed to be microscopic shells, but subsequently discovered to be the seed-vessel of freshwater plants of the genus *Chara*. See Vol. III. p. 350. *Etym.*, γυρος, *gyros*, curved, and γονος, *gonos*, seed, on account of their external structure.

HEMIPTERA. An order of insects, so called from a peculiarity in their wings, the superior being coriaceous at the base, and membranous at the apex, ἡμισυ, *hemisu*, half, and πτερον, *pteron*, wing.

HORNBLENDE. A simple mineral of a dark green or black colour, which enters largely into the composition of several varieties of the Trap-rocks.

HORNSTONE. A siliceous mineral substance, sometimes approaching nearly to flint, or common quartz. It has a conchoidal fracture, and is infusible, which distinguishes it from compact felspar.

HUMERUS. The bone of the upper arm.

HYDROPHYTES. Plants which grow in water. *Etym.*, ὑδωρ, *hydor*, water, and φυτον, *phyton*, plant.

HYPOGENE ROCKS. Those rocks which are *nether-formed*, or which have not assumed their present form and structure at the surface, such as granite, gneiss, &c. This term, which includes both the plutonic and metamorphic rocks, is substituted for *primary*, because some members of both these classes, such as granite and gneiss, are posterior to many secondary or fossiliferous rocks. *Etym.*, ὑπο, *hypo*, under, and γινομαι, *ginomai*, to be formed or produced.

ICEBERG. Great masses of ice, often the size of hills, which float in the polar and adjacent seas. *Etym.*, ice, and *berg*, German for hill.

ICHTHYOSAURUS. A gigantic fossil marine reptile, intermediate between a crocodile and a fish. *Etym.*, ιχθυς, *icthus*, a fish, and σαυρα, *saura*, a lizard.

IGNEOUS ROCKS. All rocks, such as lava, trap, and granite, known or supposed to have been melted by volcanic heat.

INCANDESCENT. White hot — having a more intense degree of heat than red heat.

INDUCTION. A consequence, inference, or general principle drawn from a number of particular facts or phenomena. The inductive philosophy, says Mr. Whewell, has been rightly described as a science which ascends from particular facts to general principles, and then descends again from these general principles to particular applications.

INFUSORY ANIMALCULES. Minute living creatures found in many *infusions;* and the term *infusori* has been given to all such animalcules, whether found in infusions or in stagnant water, vinegar, &c.

INSPISSATED. Thickened. *Etym.*, *spissus*, thick.

INVERTEBRATED ANIMALS. Animals which are not furnished with a back-bone. For a further explanation, see "Vertebrated Animals."

ISOTHERMAL. Such zones or divisions of the land, ocean, or atmosphere, which have an equal degree of mean annual warmth, are said to be isothermal, from ισος, *isos*, equal, and θερμη, *therme*, heat.

JOINTS. Fissures or lines of parting in rocks, often at right angles to the planes of stratification. The partings which divide columnar basalt into prisms are joints.

JURA LIMESTONE. The limestones belonging to the Oolitic Group constitute the chief pa of the mountains of the Jura, between France and Switzerland; and hence the geologists of the Continent have given the name to the group.

KEUPER, a German name for a member of the Upper New Red Sandstone.

KIMMERIDGE CLAY. A thick bed of clay, constituting a member of the Oolite Group. So called, because it is found well developed at Kimmeridge in the isle of Purbeck, Dorsetshire.

LACUSTRINE. Belonging to a lake. *Etym.*, *lacus*, a lake.

LAMANTINE. A living species of the herbivorous Cetacea or

whale tribe, which inhabits the mouths of rivers on the coast of Africa and South America: the sea-cow.

LAMELLIFEROUS. Having a structure consisting of thin plates or leaves like paper. *Etym.*, *lamella*, the diminutive of *lamina*, plate, and *fero*, to bear.

LAMINÆ. Latin for plates; used in geology for the smaller layers of which a stratum is frequently composed.

LANDSLIP. A portion of land that has slid down in consequence of disturbance by an earthquake, or from being undermined by water washing away the lower beds which supported it.

LAPIDIFICATION— Lapidifying process. Conversion into stone. *Etym.*, *lapis*, stone, and *fio*, to make.

LAPILLI. Small volcanic cinders. *Lapillus*, a little stone.

LAVA. The stone which flows in a melted state from a volcano.

LEPIDODENDRON, a genus of fossil plants of the Coal Measures, intermediate in character between the Lycopodiums and coniferous plants.

LEUCITE. A simple mineral found in volcanic rocks, crystallized, and of a white color. *Etym.*, λευκος, *leucos*, white.

LIAS. A provincial name for an argillaceous limestone, characterized together with its associated beds by peculiar fossils, and forming a particular group of strata, interposed between the Oolite and New Red Sandstone.

LIGNIPERDOUS. A term applied to insects which destroy wood. *Etym.*, *lignum*, wood, and *perdo*, to destroy.

LIGNITE. Wood converted into a kind of coal. *Etym.*, *lignum*, wood.

LITHODOMI. Molluscous animals which form holes in solid rocks in which they lodge themselves. The holes are not perforated mechanically, but the rock appears to be dissolved. *Etym.*, λιθος, *lithos*, stone, and δεμω, *demo*, to build.

LITHOGENOUS POLYPS. Animals which form coral.

LITHOGRAPHIC STONE. A slaty compact limestone, of a yellowish colour and fine grain, used in lithography, which is the art of drawing upon and printing from stone. *Etym.*, λιθος, *lithos*, stone, and γραφω, *grapho*, to write.

LITHOIDAL. Having a stony structure.

LITHOLOGICAL. A term expressing the stony structure or char-

acter of a mineral mass. We speak of the lithological character of a stratum as distinguished from its zoological character. *Etym.*, λιθος, *lithos*, stone, and λογος, *logos*, discourse.

LITHOPHAGI. Molluscous animals which form holes in solid stones. See "Lithodomi." *Etym.*, λιθος, *lithos*, stone, and φαγειν, *phagein*, to eat.

LITHOPHYTES. The animals which form Stone-coral.

LITTORAL. Belonging to the shore. *Etym.*, *littus*, the shore.

LOAM. A mixture of sand and clay.

LOPHIODON. A genus of extinct quadrupeds, allied to the tapir, named from eminences on the teeth.

LYCOPODIACEÆ. Plants of an inferior degree of organization to Coniferæ, some of which they very much resemble in foliage, but all recent species are infinitely smaller. Many of the fossil species are as gigantic as recent Coniferæ. Their mode of reproduction is analogous to that of ferns. In English they are called club-mosses, generally found in mountainous heaths in the north of England.

LYDIAN STONE. Flinty slate; a kind of quartz or flint, allied to Hornstone, but of a greyish black colour.

MACIGNO. In Italy this term has been applied to a siliceous sandstone sometimes containing calcareous grains, mica, &c.

MADREPORE. A genus of corals, but generally applied to all the corals distinguished by superficial star-shaped cavities. There are several fossil species.

MAGNESIAN LIMESTONE. An extensive series of beds, the geological position of which is immediately above the Coal Measures; so called, because the limestone, the principal member of the series, contains much of the earth magnesia as a constituent part.

MAMMIFEROUS. Mammifers. Animals which give suck to their young. To this class all the warm-blooded quadrupeds, and the Cetacea, or whales, belong. *Etym.*, *mamma*, a breast, *fero*, to bear.

MAMMILLARY. A surface which is studded over with rounded projections. *Etym*, *mammilla*, a little breast or pap.

MAMMOTH. An extinct species of the elephant (*E. primigenius*), of which the fossil bones are frequently met with in

various countries. The name is of Tartar origin, and is used in Siberia for animals that burrow under ground.

MANATI. One of the Cetacea, the sea-cow, or lamantine (*Trichechus manatus*, Lin.)

MARL. A mixture of clay and lime; usually soft, but sometimes hard, in which case it is called indurated marl.

MARSUPIAL ANIMALS. A tribe of quadrupeds having a sack or pouch under the belly, in which they carry their young. The kangaroo is a well-known example. *Etym.*, *marsupium*, a purse.

MASTODON. A genus of fossil extinct quadrupeds allied to the elephants; so called from the form of the hind teeth or grinders, which have their surface covered with conical mammillary crests. *Etym.*, μαστος, *mastos*, pap, and οδων, *odon*, tooth.

MATRIX. If a simple mineral or shell, in place of being detached, be still fixed in a portion of rock, it is said to be in its matrix. *Matrix*, womb.

MECHANICAL ORIGIN, ROCKS OF. Rocks composed of sand, pebbles, or fragments, are so called, to distinguish them from those of a uniform crystalline texture, which are of chemical origin.

MEDUSÆ. A genus of marine radiated animals, without shells; so called, because their organs of motion spread out like the snaky hair of the fabulous Medusa.

MEGALOSAURUS. A fossil gigantic amphibious animal of the saurian or lizard and crocodile tribe. *Etym.*, μεγαλη, *megale*, great, and σαυρα, *saura*, lizard.

MEGATHERIUM. A fossil extinct quadruped, resembling a gigantic sloth. *Etym.*, μεγα, *mega*, great, and θηριον, *therion*, wild beast.

MELASTOMA. A genus of MELASTOMACEA, an order of exotic plants of the evergreen tree, and shrubby kinds. *Etym.*, μελας, *melas*, black, and στομα *stoma*, mouth; because the fruit of one of the species stains the lips.

MESOTYPE. A simple mineral, white, and needle-shaped, one of the Zeolite family, frequently met with in the Traprocks.

METAMORPHIC ROCKS. A stratified division of hypogene rocks, highly crystalline, such as gneiss and mica-schist, and so

named because they have been *altered* by plutonic action. *Etym.*, μετα, *meta*, trans, and μορφη, *morphe*, form.

MICA. A simple mineral, having a shining silvery surface, and capable of being split into very thin elastic leaves or scales. It is often called *talc* in common life; but mineralogists apply the term talc to a different mineral. The brilliant scales in granite are mica. *Etym.*, *mico*, to shine.

MICA-SLATE, MICA SCHIST, MICACEOUS SCHISTUS. One of the metamorphic or crystalline stratified rocks, of the hypogene class, which is characterized by being composed of a large proportion of mica united with quartz.

MIOCENE. A division of tertiary strata intervening between the Eocene and Pliocene formations; so called, because a minority of its fossil shells are referable to living species. *Etym.*, μειων, *meion*, less, and κάινος, *kainos*, recent.

MOLASSE. A provincial name for a soft green sandstone, associated with marl and conglomerates, belonging to the Miocene Tertiary Period, extensively developed in the lower country of Switzerland. *Etym.*, French, *molle*, soft.

MOLLUSCA, MOLLUSCOUS ANIMALS. Animals, such as shellfish, which, being devoid of bones, have soft bodies. *Etym.*, *mollis*, soft.

MONAD. The smallest of visible animalcules, spoken of by Buffon and his followers as constituting the elementary molecules of organic beings.

MONITOR. An animal of the saurian or lizard tribe, species of which are found in both the fossil and recent state.

MONOCOTYLEDONOUS. A grand division of the vegetable kingdom (including palms, grasses, Lilaceæ, &c.), founded on the plant having only one *cotyledon*, or seed-lobe. *Etym.*, μονος, *monos*, single.

MORAINE, a Swiss term for the débris of rocks brought into valleys by glaciers. See Vol. I. p. 377.

MOSCHUS. A quadruped resembling the chamois or mountain goat, from which the perfume musk is obtained.

MOUNTAIN LIMESTONE, or CARBONIFEROUS LIMESTONE. A series of limestone strata of marine origin, usually forming the lowest member of the Coal Measures.

MOYA. A term applied in South America to mud poured out from volcanos during eruptions.

MULTILOCULAR. Many-chambered; a term applied to those shells which, like the nautilus, ammonite, and others, are divided into many compartments. *Etym.*, *multus*, many, and *loculus*, a partition.

MURIATE OF SODA. The scientific name for common culinary salt, because it is composed of muriatic acid and the alkali soda.

MUSACEÆ. A family of tropical monocotyledonous plants, including the banana and plantains.

MUSCHELKALK. A limestone, belonging to the Upper New Red Sandstone group. Its position is between the Magnesian Limestone and the Lias. This formation has not yet been found in England, and the German name is adopted by English geologists. The word means shell-limestone. *Etym.*, *muschel*, shell, and *kalkstein*, limestone.

NAPHTHA. A very thin, volatile, inflammable, and fluid mineral substance, of which there are springs in many countries, particularly in volcanic districts.

NENUPHAR. A yellow water-lily.

NEW RED SANDSTONE. A formation so named, because it consists chiefly of sandy and argillaceous strata, the predominant colour of which is brick-red, but containing portions which are of a greenish-grey. These occur often in spots and stripes, so that the series has sometimes been called the variegated sandstone. This formation is divided into the Upper New Red in which the Muschelkalk is included, and the Lower New Red of which the Magnesian Limestone is a member.

NODULE. A rounded irregular-shaped lump or mass. *Etym.*, diminutive of *nodus*, knot.

NORMAL GROUPS. Groups of certain rocks taken as a rule or standard. *Etym.*, *norma*, rule or pattern.

NUCLEUS. A solid central piece, around which other matter is collected. The word is Latin for kernel.

NUMMULITES. An extinct genus of the order of molluscous animals, called Cephalopoda, of a thin lenticular shape, internally divided into small chambers. *Etym.*, *nummus*, Latin for money, and λιθος, *lithos*, stone, from its resemblance to a coin.

OBSIDIAN. A volcanic product, or species of lava, very like common green bottle-glass, which is almost black in large masses, but semi-transparent in thin fragments. Pumice-stone is obsidian in a frothy state; produced, most probably, by water that was contained in or had access to the melted stone, and converted into steam. There are very often portions in masses of solid obsidian, which are partially converted into pumice.

OCHRE. A yellow powder, a combination of some earth with oxide of iron.

OGYGIAN DELUGE. A great inundation mentioned in fabulous history, supposed to have taken place in the reign of Ogyges, in Attica, whose death is fixed in Blair's Chronological Tables in the year 1764 before Christ. See Vol. II. p. 140.

OLD RED SANDSTONE. A formation immediately below the Carboniferous Group. The term Devonian has been recently proposed for strata of this age, because in Devonshire they are largely developed, and contain many organic remains.

OLIVINE. An olive-coloured, semi-transparent, simple mineral, very often occurring in the form of grains and of crystals in basalt and lava.

OOLITE, OOLITIC. A limestone; so named, because it is composed of rounded particles, like the roe or eggs of a fish. The name is also applied to a large group of strata, characterized by peculiar fossils, in which limestone of this texture occurs. *Etym.*, *ωον*, *oon*, egg, and *λιθος*, *lithos*, stone.

OPALIZED WOOD. Wood petrified by siliceous earth, and acquiring a structure similar to the simple mineral called opal.

OPHIDIOUS REPTILES. Vertebrated animals, such as snakes and serpents. *Etym.*, *οφις*, *ophis*, a serpent.

ORGANIC REMAINS. The remains of animals and plants (*organized* bodies) found in a fossil state.

ORTHOCERATA, or ORTHOCERÆ. An extinct genus of the order of molluscous animals, called Cephalopoda, that inhabited a long-chambered conical shell, like a straight horn. *Etym.*, *ορθος*, *orthos*, straight, and *κερας*, *ceras*, horn.

OSSEOUS BRECCIA. The cemented mass of fragments of bones of extinct animals found in caverns and fissures. *Osseus* is a Latin adjective, signifying bony.

OSTEOLOGY. That division of anatomy which treats of the bones; from οστεον, *osteon*, and λογος, *logos*, a discourse.

OUTLIERS. When a portion of the stratum occurs at some distance, detached from the general mass of the formation to which it belongs, some practical mineral surveyors call it an *outlier*, and the term is adopted in geological language.

OVATE. The shape of an egg. *Etym.*, *ovum*, egg.

OVIPOSITING. The laying of eggs.

OXIDE. The combination of a metal with oxygen; rust is oxide of iron.

OXYGEN. One of the constituent parts of the air of the atmosphere; that part which supports life. For a further explanation of the word, consult elementary works on chemistry.

PACHYDERMATA. An order of quadrupeds, including the elephant, rhinoceros, horse, pig, &c., distinguished by having thick skins. *Etym.*, παχυς, *pachus*, thick, and δερμα, *derma*, skin or hide.

PACHYDERMATOUS. Belonging to Pachydermata.

PALÆOTHERIUM, PALEOTHERE. A fossil extinct quadruped, belonging to the order Pachydermata, resembling a pig, or tapir, but of great size. *Etym.*, παλαιος, *palaios*, ancient, and θηριον, *therion*, wild beast.

PALEONTOLOGY. The science which treats of fossil remains, both animal and vegetable. *Etym.*, παλαιος, *palaios*, ancient, οντα, *onta*, beings, and λογος, *logos*, a discourse.

PELAGIAN, PELAGIC. Belonging to the *deep* sea. *Etym.*, *pelagus*, sea.

PEPERINO. An Italian name for a particular kind of volcanic rock, formed, like tuff, by the cementing together of volcanic sand, cinders, or scoriæ, &c.

PETROLEUM. A liquid mineral pitch, so called because it is seen to ooze like oil out of the rock. *Etym.*, *petra*, rock, and *oleum*, oil.

PHÆNOGAMOUS or PHANEROGAMIC PLANTS. A name given by Linnæus to those plants in which the reproductive organs are apparent. *Etym.*, φανερος, *phaneros*, evident, or φαινω, *phaino*, to show, and γαμος, *gamos*, marriage.

PHLEGRÆAN FIELDS. Campi Phlegræi, or "the Burnt Fields."

The country around Naples, so named by the Greeks, from the traces of igneous action every where visible.

PHONOLITE. See "Clinkstone."

PHRYGANEA. A genus of four-winged insects, the larvæ of which, called caddis-worms, are used by anglers as a bait.

PHYSICS. The department of science which treats of the properties of natural bodies, laws of motion, &c.; sometimes called natural philosophy and mechanical philosophy. *Etym.*, φυσις, *physis*, nature.

PHYTOLOGY, PHYTOLOGICAL. The department of science which relates to plants—synonymous with botany and botanical. *Etym.*, φυτον, *phyton*, plant, and λογος, *logos*, discourse.

PHYTOPHAGOUS. Plant-eating. *Etym.*, φυτον, *phyton*, plant, and φαγειν, *phagein*, to eat.

PISOLITE. A stone possessing a structure like an agglutination of pease. *Etym.*, πισον, *pison*, pea, and λιθος, *lithos*, stone.

PISTIA. Vol. III. p. 126. The plant mentioned by Malte-Brun is probably the *Pistia Stratiotes*, a floating plant, related to English duck-weed, but very much larger.

PIT COAL. Ordinary coal; called so, because it is obtained by sinking pits in the ground.

PITCHSTONE. A rock of a uniform texture, belonging to the unstratified and volcanic classes, which has an unctuous appearance like indurated pitch.

PLASTIC CLAY. One of the beds of the Eocene Tertiary Period; so called, because it is used for making pottery. The formation to which this name is applied is a series of beds chiefly sands, with which the clay is associated. *Etym.*, πλασσω, *plasso*, to form or fashion.

PLESIOSAURUS. A fossil extinct amphibious animal, resembling the saurian, or lizard and crocodile tribe. *Etym.*, πλησιον, *plesion*, near to, and ϛαυϱα, *saura*, a lizard.

PLIOCENE, OLDER and NEWER. Two divisions of the tertiary period which are the most modern, and of which the largest part of the fossil shells are of recent species. *Etym.*, πλειων, *pleion*, more, and καινος, *kainos*, recent.

PLUTONIC ACTION. The influence of volcanic heat and other subterranean causes under pressure.

PLUTONIC ROCKS. Granite, porphyry, and other igneous rocks,

supposed to have consolidated from a melted state at a great depth from the surface,

Polyparia. **Corals.** A numerous class of invertebrated animals, belonging to the great division called Radiata.

Porphyry. An unstratified or igneous rock. The term is as old as the time of Pliny, and was applied to a red rock with small, angular, white bodies diffused through it, which are crystallized felspar, brought from Egypt. The term is hence applied to every species of unstratified rock in which detached crystals of felspar or some other mineral are diffused through a base of other mineral composition. *Etym.*, πορφυρα, *porphyra*, purple.

Portland Limestone, Portland Beds. A series of limestone strata, belonging to the upper part of the Oolite Group, found chiefly in England in the island of Portland on the coast of Dorsetshire. The great supply of the building stone used in London is from these quarries.

Pozzuolana. Volcanic ashes, largely used as mortar for buildings, similar in nature to what is called in this country Roman cement. It gets its name from Puzzuoli, a town in the bay of Naples, from which it is shipped in large quantities to all parts of the Mediterranean.

Precipitate. Substances which, having been dissolved in a fluid, are separated from it by combining chemically and forming a solid, which falls to the bottom of the fluid. This process is the opposite to that of chemical solution.

Producta. An extinct genus of fossil bivalve shells, occurring only in the older secondary rocks. It is closely allied to the living genus Terebratula.

Pterodactyl. A flying reptile: species of this genus have been found in the Oolite and Muschelkalk. Some of the finger joints are lengthened, so as to serve as the expansors of a membranous wing. Hence the name *wing-fingered*. *Etym.*, πτερον, *pteron*, a wing, and δακτυλος, *dactylos*, a finger.

Pubescence. The soft hairy down on insects. *Etym.*, *pubesco*, the first growth of the beard.

Puddingstone. See "Conglomerate."

Pumice. A light spongy lava, chiefly felspathic, of a white colour, produced by gases, or watery vapour getting access to the particular kind of glassy lava called obsidian, when in

a state of fusion — it may be called the froth of melted volcanic glass. The word comes from the Latin name of the stone, *pumex*.

PURBECK LIMESTONE, PURBECK BEDS. Limestone strata, belonging to the Wealden Group, which intervenes between the Green-sand and the Oolite.

PYRITES. (Iron.) A compound of sulphur and iron, found usually in yellow shining crystals like brass, and in almost every rock, stratified and unstratified. The shining metallic bodies so often seen in common roofing slate, are a familiar example of the mineral. The word is Greek, and comes from πυρ, *pyr*, fire; because, under particular circumstances, the stone produces spontaneous heat, and even inflammation.

PYROMETER. An instrument for measuring intense degrees of heat.

QUADRUMANA. The order of mammiferous animals to which apes belong. *Etym.*, *quadrus*, a derivative of the Latin word for the number four, and *manus*, hand, the four feet of those animals being in some degree usable as hands.

QUA-QUA-VERSAL DIP. The dip of beds to all points of the compass around a centre, as in the case of beds of lava round the crater of a volcano. *Etym.*, *quâ-quâ versum*, on every side.

QUARTZ. A German provincial term, universally adopted in scientific language for a simple mineral composed of pure silex, or earth of flints: rock-crystal is an example.

QUARTZITE or QUARTZ ROCK. An aggregate of grains of quartz, sometimes passing into compact quartz.

RED MARL. A term often applied to the New Red Sandstone.

RETICULATE. A structure of cross lines, like a net, is said to be reticulated, from *rete*, a net.

ROCK SALT. Common culinary salt, or muriate of soda, found in vast solid masses or beds, in different formations, extensively in the New Red Sandstone formation, as in Cheshire; and it is then called *rock*-salt.

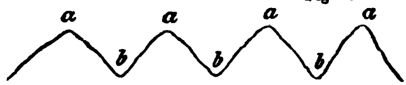
RUBBLE. A term applied by quarry-men to the upper fragmentary and decomposed portion of a mass of stone.

RUMINANTIA. Animals which ruminate or chew the cud, such as the ox, deer, &c. *Etym.*, the Latin verb *rumino*, meaning the same thing.

SACCHAROID, SACCHARINE. When a stone has a texture resembling that of loaf-sugar. *Etym.*, σακχαρ, *sacchar*, sugar, and ειδος, *eidos*, form.

SALIENT ANGLE. In a zigzag line, *a a* are the salient angles, *b b* the re-entering angles. *Etym.*, *salire*, to leap or bound forward.

Fig. 101.



SALT SPRINGS. Springs of water containing a large quantity of common salt. They are very abundant in Cheshire and Worcestershire, and culinary salt is obtained from them by mere evaporation.

SANDSTONE. Any stone which is composed of an agglutination of grains of sand, whether calcareous, siliceous, or of any other mineral nature.

SAURIAN. Any animal belonging to the lizard tribe. *Etym.*, σαυρα, *saura*, a lizard.

SCHIST is often used as synonymous with slate; but it may be very useful to distinguish between a schistose and a slaty structure. The hypogene or primary *schists*, as they are termed, such as gneiss, mica-schist, and others, cannot be split into an indefinite number of parallel laminæ, like rocks which have a true slaty cleavage. The uneven schistose layers of mica-schist and gneiss are probably layers of deposition, which have assumed a crystalline texture. See "Cleavage." *Etym.*, *schistus*, adj. Latin, that which may be split.

SCHISTOSE ROCKS. See "Schist."

SCORIÆ. Volcanic cinders. The word is Latin for cinders.

SEAMS. Thin layers which separate two strata of greater magnitude.

SECONDARY STRATA. An extensive series of the stratified rocks which compose the crust of the globe, with certain characters in common, which distinguish them from another series below them called *primary*, and from a third series above them called *tertiary*.

SECULAR REFRIGERATION. The periodical cooling and con-

solidation of the globe from a supposed original state of fluidity from heat. *Sæculum*, age or period.

SEDIMENTARY ROCKS are those which have been formed by their materials having been thrown down from a state of suspension or solution in water.

SELENITE. Crystallized gypsum, or sulphate of lime — a simple mineral.

SEPTARIA. Flattened balls of stone, generally a kind of ironstone, which, on being split, are seen to be separated in their interior into irregular masses. *Etym.*, *septa*, inclosures.

SERPENTINE. A rock usually containing much magnesian earth, for the most part unstratified, but sometimes appearing to be an altered or metamorphic stratified rock. Its name is derived from frequently presenting contrasts of colour, like the skin of some serpents.

SHALE. A provincial term, adopted by geologists, to express an indurated slaty clay. *Etym.*, German *schalen*, to peel, to split.

SHELL MARL. A deposit of clay, peat, and other substances mixed with shells, which collects at the bottom of lakes.

SHINGLE. The loose and completely water-worn gravel on the sea-shore.

SILEX. The name of one of the pure earths, being the Latin word for *flint*, which is wholly composed of that earth. French geologists have applied it as a generic name for all minerals composed entirely of that earth, of which there are many of different external forms.

SILICA. One of the pure earths. *Etym.*, *silex*, flint, because found in that mineral.

SILICATE. A chemical compound of silica and another substance, such as silicate of iron. Consult elementary works on chemistry.

SILICEOUS. Of or belonging to the earth of flint. *Etym.*, *silex*, which see. A siliceous rock is one mainly composed of silex.

SILICIFIED. Any substance that is petrified or mineralized by *siliceous* earth.

SILT. The more comminuted sand, clay, and earth, which is transported by running water. It is often accumulated by currents in banks. Thus the mouth of a river is silted up

when its entrance into the sea is impeded by such accumulation of loose materials.

SIMPLE MINERAL. Individual mineral substances, as distinguished from rocks, which last are usually an aggregation of simple minerals. They are not simple in regard to their nature; for, when subjected to chemical analysis, they are found to consist of a variety of different substances. Pyrites is a simple mineral in the sense we use the term, but it is a chemical compound of sulphur and iron.

SINTER, CALCAREOUS or SILICEOUS. A German name for a rock precipitated from mineral waters. *Etym.*, *sintern*, to drop.

SLATE. See "Cleavage" and "Schist."

SOLFATARA. A volcanic vent from which sulphur, sulphureous, watery, and acid vapours and gases are emitted.

SPORULES. The reproductory corpuscula (minute bodies) of cryptogamic plants. *Etym.*, σπορα, *spora*, a seed.

STALACTITE. When water holding lime in solution deposits it as it drops from the roof of a cavern, long rods of stone hang down like icicles, and these are called *stalactites*. *Etym.*, σταλαζω, *stalazo*, to drop.

STALAGMITE. When water holding lime in solution drops on the floor of a cavern, the water evaporating leaves a crust composed of layers of limestone: such a crust is called *stalagmite*, from σταλαγμα, *stalagma*, a drop, in opposition to *stalactite*, which see.

STATICAL FIGURE. The figure which results from the equilibrium of forces. From στατος, *statos*, stable, or standing still.

STERNUM. The breast-bone, or the flat bone occupying the front of the chest.

STILBITE. A crystallized simple mineral, usually white, one of the Zeolite family, frequently included in the mass of the Trap-rocks.

STRATIFIED. Rocks arranged in the form of *strata*, which see.

STRATIFICATION. An arrangement of rocks in *strata*, which see.

STRATA, STRATUM. The term stratum, derived from the Latin verb *struo*, to strew or lay out, means a bed or mass of matter spread out over a certain surface by the action of water, or in some cases by wind. The deposition of successive layers of sand and gravel in the bed of a river, or in a canal, affords a perfect illustration both of the form and origin of stratification.

A large portion of the masses constituting the earth's crust are thus stratified, the successive strata of a given rock preserving a general parallelism to each other; but the planes of stratification not being perfectly parallel throughout a great extent like the planes of *cleavage*, which see.

STRIKE. The direction or line of bearing of strata, which is always at right angles to their prevailing dip.

STUFAS. Jets of steam issuing from fissures in volcanic regions at a temperature often above the boiling point.

SUBAPENNINES. Low hills which skirt or lie at the foot of the great chain of the Apennines in Italy. The term Subapennine is applied geologically to a series of strata of the Older Pliocene Period.

SYENITE. A kind of granite; so called, because it was brought from Syene in Egypt.

TALUS. When fragments are broken off by the action of the weather from the face of a steep rock, as they accumulate at its foot, they form a sloping heap, called a talus. The term is borrowed from the language of fortification, where *talus* means the outside of a wall of which the thickness is diminished by degrees, as it rises in height, to make it the firmer.

TARSI. The feet in insects, which are articulated, and formed of five or a less number of joints.

TERTIARY STRATA. A series of sedimentary rocks, with characters which distinguish them from two other great series of strata — the secondary and primary — which lie *beneath* them.

TESTACEA. Molluscous animals, having a shelly covering. *Etym.*, *testa*, a shell, such as snails, whelks, oysters, &c.

THERMAL. Hot. *Etym*, θερμος, *thermos*, hot.

THERMO-ELECTRICITY. Electricity developed by heat.

THIN OUT. When a stratum, in the course of its prolongation in any direction, becomes gradually less in thickness, the two surfaces approach nearer and nearer; and when at last they meet, the stratum is said to thin out or disappear.

TRACHYTE. A variety of lava essentially composed of glassy felspar, and frequently having detached crystals of felspar in the base or body of the stone, giving it the structure of por-

phyry. It sometimes contains hornblende and augite; and when these last predominate, the trachyte passes into the varieties of trap called Greenstone, Basalt, Dolorite, &c. The term is derived from τραχυς, *trachus*, rough, because the rock has a peculiar rough feel.

TRAP and TRAPPEAN ROCKS. Volcanic rocks composed of felspar, augite, and hornblende. The various proportions and state of aggregation of these simple minerals, and differences in external forms, give rise to varieties, which have received distinct appellations, such as Basalt, Amygdaloid, Dolorite, Greenstone, and others. The term is derived from *trappa*, a Swedish word for stair, because the rocks of this class sometimes occur in large tabular masses, rising one above another, like steps.

TRAVERTIN. A white concretionary limestone, usually hard and semi-crystalline, deposited from the water of springs holding lime in solution. — *Etym.* This stone was called by the ancients Lapis Tiburtinus, the stone being formed in great quantity by the river Anio, at Tibur, near Rome. Some suppose travertin to be an abbreviation of trasteverino from transtiburtinus.

TRIPOLI. The name of a powder used for polishing metals and stones, first imported from Tripoli, which, as well as a certain kind of siliceous stone of the same name, has been lately found to be composed of the flinty cases of Infusoria.

TROPHI, of Insects. Organs which form the mouth, consisting of an upper and under lip, and comprising the parts called mandibles, maxillæ, and palpi.

TUFA, CALCAREOUS. A porous rock deposited by calcareous waters on their exposure to the air, and usually containing portions of plants and other organic substances incrusted with carbonate of lime. The more solid form of the same deposit is called "travertin," into which it passes.

TUFA, VOLCANIC. See "Tuff."

TUFACEOUS. A rock with the texture of tuff, or tufa, which see.

TUFF, or TUFA, VOLCANIC. An Italian name for a variety of volcanic rock of an earthy texture, seldom very compact, and composed of an agglutination of fragments of scoriæ and loose materials ejected from a volcano.

TURBINATED. Shells which have a spiral or screw-form structure. *Etym.*, *turbinatus*, made like a top.

TURRILITE. An extinct genus of chambered shells, allied to the Ammonites, having the siphuncle near the dorsal margin.

UNCONFORMABLE. See "Conformable."

UNOXIDIZED, UNOXIDATED. Not combined with oxygen.

VEINS, MINERAL. Cracks in rocks filled up by substances different from the rock, which may either be earthy or metallic. Veins are sometimes many yards wide; and they ramify or branch off into innumerable smaller parts, often as slender as threads, like the veins in an animal, hence their name.

VERTEBRATED ANIMALS. A great division of the animal kingdom, including all those which are furnished with a back-bone, as the Mammalia, birds, reptiles, and fishes. The separate joints of the back-bone are called *vertebræ*, from the Latin verb *verto*, to turn.

VESICLE. A small, circular, inclosed space, like a little bladder. *Etym.*, diminutive of *vesica*, Latin for a bladder.

VITRIFICATION. The conversion of a body into glass by heat.

VOLCANIC BOMBS. Volcanos throw out sometimes detached masses of melted lava, which, as they fall, assume rounded forms (like bomb-shells), and are often elongated into a pear shape.

VOLCANIC FOCI. The subterranean centres of action in volcanos, where the heat is supposed to be in the highest degree of energy.

WACKE. A rock nearly allied to basalt, of which it may be regarded as a soft and earthy variety.

WARP. The deposit of muddy waters, artificially introduced into low lands. See Vol. II. p. 109.

ZEOLITE. A family of simple minerals, including stilbite, mesotype, analcime, and some others, usually found in the trap or volcanic rocks. Some of the most common varieties swell or boil up when exposed to the blow-pipe, and hence the name of ζεω, *zeo*, to boil, and λιθος, *lithos*, stone.

ZOOPHYTES. Corals, sponges, and other aquatic animals allied to them; so called because, while they are the habitation of animals, they are fixed to the ground, and have the forms of plants. *Etym.*, ζωον, *zoon*, animal, and φυτον, *phyton*, plant.

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